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...RT DATE

3. REPORT TYPE AND DATES COVERED
22-24 JUNE 1993

4. TITLE AND SUBTITLE
Sixteenth ARPA Systems and Technology Symposium

5. FUNDING NUMBERS

6. AUTHOR(S)

DTIC
ELECTE
AUG 17 1993
S C D

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
ARPA
3701 N. Fairfax Drive
Arlington, VA 22203

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE
DISTRIBUTION UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The Sixteenth Advanced Research Projects Agency (ARPA) Systems and Technology Symposium was held June 22-24, 1993 at the Naval War College in Newport, Rhode Island.

These proceedings include briefing materials and corresponding text presented by Key Speakers, ARPA Technical Office Directors, and ARPA Program Managers. The presentations are organized according to the final symposium agenda. Award citations and a list of participating organizations are also included.

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14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

NSN 7540-01-280-5500

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PROCEEDINGS

SIXTEENTH
ADVANCED RESEARCH PROJECTS AGENCY

SYSTEMS AND TECHNOLOGY SYMPOSIUM

22 - 24 JUNE 1993

HOSTED BY:

NAVAL WAR COLLEGE
NEWPORT, RHODE ISLAND

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*The presentations are organized according to the Final Agenda.

OVERVIEW

The Sixteenth Advanced Research Projects Agency (ARPA) Systems and Technology Symposium was held June 22-24, 1993 at the Naval War College in Newport, Rhode Island.

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PRESS ADVISORY

PRESS ADVISORY June 21, 1993

Congressman Ron Machtley will speak to the Department of Defense Advanced Research Projects Agency 16th Systems and Technology Symposium at 9:20 a.m. on Tuesday, June 22, 1993, in the Spruance Auditorium of the Naval War College, Newport, Rhode Island.

Deputy Secretary of Defense William J. Perry will give the Symposium's first keynote speech at 2 p.m. on Wednesday, June 23, in the Spruance Auditorium. ~~The second keynote speech will be given by Deputy Assistant to the President for Economic Policy W. Bowman Cutter at 2:30 p.m.~~

The Symposium is designed to acquaint Defense officials and contractors with details of ARPA programs and technologies, such as dual-use technologies, advanced computing and software, advanced materials and microelectronics, and more.

The Symposium also includes presentations by the ARPA director and managers discussing ARPA Vision (afternoon of June 22), Information Technology (morning of June 23) and Affordable Acquisition (afternoon of June 23). Media are invited to attend any of these unclassified sessions scheduled for June 22 and 23. (*Sessions on June 24 discussing* future military technologies will be classified and closed to the media.)

At 7:30 p.m on June 22, ARPA Director Gary Denman will present ARPA Awards for Outstanding Performance. Media are also invited to attend the awards ceremony, which will be held on the Naval War College grounds.

The Advanced Research Projects Agency (ARPA) is the central research organization for the Department of Defense, with primariy respoinsibility to maintain U.S. technological superiority over potential adversaries. It pursues imaginative and innovative research and development projects having significant potential for both military and commercial applications, and supports a national technology base that serves both civilian and military purposes.

A detailed agenda is available.

-END-

FUTURE MILITARY TECHNOLOGY SESSION
JUNE 24, 1993
SESSION CHAIR: MR. RONALD D. MURPHY

0830 Mr. Ronald D. Murphy, Director, Advanced Systems Technology Office, ARPA
Introduction

0840 Lt Col Michael S. Francis, USAF, Advanced Systems Technology Office, ARPA
Aeronautical Systems

0910 Mr. Thomas Hafer, Advanced Systems Technology Office, ARPA
Land Combat Systems

0940 Mr. Charles E. Stuart, Director, Maritime Systems Technology Office, ARPA
Maritime Systems

1010 Break

1030 Lt Col Lee F. Demitry, USAF, Advanced Systems Technology Office, ARPA
Space Systems

1100 COL Robert P. Reddy, USA, Advanced Systems Technology Office, ARPA
Readiness and Training

1130 Dr. Judith A. Daly, Advanced Systems Technology Office, ARPA
War Breaker and Evolving Military Technology

1230 Mr. Ronald D. Murphy, Director, Advanced Systems Technology Office, ARPA
Session Summary

1245 Adjourn Symposium

FINAL SYMPOSIUM AGENDA

PLENARY SESSION
JUNE 22, 1993

0845 Rear Admiral Joseph C. Strasser, President, Naval War College, Newport, RI
NWC Welcome

0900 Dr. Duane A. Adams, Deputy Director, Advanced Research Projects Agency
Introduction to the 16th ARPA Systems & Technology Symposium

0915 Dr. Gary L. Denman, Director, Advanced Research Projects Agency
Introduction of Key Plenary Speaker

0920 Congressman Ron Machtley (R-Rhode Island)

0950 Dr. Gary L. Denman, Director, Advanced Research Projects Agency
Overview of ARPA Mission

1020 Break *(Turn In Questions At The Start Of The Break)*

1050 Dr. Gary L. Denman, Director, Advanced Research Projects Agency
Selected Question Card Responses

1130 Dr. H. Lee Buchanan, Director, Defense Sciences Office, ARPA
Dual Use Technologies

1200 Lunch

ARPA VISION SESSION
JUNE 22, 1993
SESSION CHAIR: DR. H. LEE BUCHANAN

1330 Dr. Michael F. McGrath, Software & Intelligence Systems Technology Office, ARPA
Affordability

1400 Dr. Lance A. Glasser, Director, Electronic Systems Technology Office, ARPA
Innovative Technologies

1430 Mr. Ronald D. Murphy, Director, Advanced Systems Technology Office, ARPA
Future Military Technologies

1520 Break

1550 Dr. Duane A. Adams, Deputy Director, Advanced Research Projects Agency
Information Technologies and the National Information Infrastructure

1620 Dr. Gary L. Denman, Director, Advanced Research Projects Agency
Session Summary

1730 Awards and Outdoor Clambake
1730 Reception
1830 Clambake Starts
1930 Awards

INFORMATION TECHNOLOGY SESSION
JUNE 23, 1993
SESSION CHAIR: DR. DUANE A. ADAMS

0830 Mr. Stephen L. Squires, Director, Computing Systems Technology Office, ARPA
HPC and Computing Systems

0900 Dr. Paul V. Mockapetris, Computing Systems Technology Office, ARPA
High Performance Networks

0930 Lt Col Brian Boesch, USAF, Computing Systems Technology Office, ARPA
Embedded Systems

1000 Break

1020 Mr. John T. Foreman, Software & Intelligence Systems Technology Office, ARPA
Software Engineering

1050 Dr. Edward W. Thompson, Director, Software & Intelligence Systems Technology Office, ARPA
Intelligent Systems

1110 Lt Col Stephen E. Cross, USAF, Software & Intelligence Systems Technology Office, ARPA
Portable Joint Task Force and Command & Control

1130 Dr. Kaigham J. Gabriel, Electronic Systems Technology Office, ARPA
Enabling Technology

1200 Dr. Jane Alexander, Microelectronics Technology Office, ARPA
Ultra Dense, Ultra Fast Computing Components

1230 Lunch

KEYNOTE ADDRESS
JUNE 23, 1993

1400 Honorable William J. Perry, Deputy Secretary of Defense

MANUFACTURING TECHNOLOGIES SESSION
JUNE 23, 1993
SESSION CHAIR: DR. MICHAEL F. McGRATH

1430 Dr. Bert Hui and Dr. Benjamin Wilcox, Defense Sciences Office, ARPA
Materials and Applied Science

1500 Mr. Sven A. Roosild, Deputy Director, Microelectronics Technology Office, ARPA
Microelectronics

Mr. Raymond S. Balcerak, Microelectronics Technology Office, ARPA
Flexible Manufacturing of Infrared Focal Plane Arrays

1545 Break

1605 Dr. Lance A. Glasser, Director, Electronic Systems Technology Office, ARPA
Electronic Systems

1705 Dr. Michael F. McGrath, Software & Intelligence Systems Technology Office, ARPA
Session Summary

1715 No Host Reception on Colbert Plaza

ARPA AWARD FOR OUTSTANDING PERFORMANCE BY AN AGENT

PRESENTED TO THE X-31 INTERNATIONAL TEST ORGANIZATION (ITO)

- Accepting this Award:

  NAVY Mr. Charles Johnson

  AIR FORCE Mr. Floyd Johnson

  NASA Although they couldn't be with us tonight, I'd like to recognize Mr. Gary Trippensee and Mr. Bob Meyer from the NASA-Ames-Dryden Team.

- On February 10, 1992, ARPA activated the I.T.O. at the Ames-Dryden Flight Research Facility to execute the X-31 flight test program. The ITO is comprised of representatives from ARPA, the Navy, the Air Force, NASA, the Federal Republic of Germany, Rockwell International and Deutsche Aerospace.

- This organization is unique in the history of experimental aircraft development and test efforts as the first X-Plane program to be co-managed in cooperation with a foreign government. Furthermore, it involves multiple agencies from both countries.

- Mr. Charles Johnson, the ARPA Agent and Navy X-31 Program Manager; Mr. Gary Trippensee, the current ITO Director and NASA X-31 Project Manager; and Mr. Joe Cosenza, the former Chief of the Wright Laboratories Investment Strategy Division, all deserve credit for their management skills, teamwork, and leadership in activating, integrating, and leading the I.T.O.

- Individually and in cooperation, these three individuals have successfully managed day-to-day technical issues, resource allocations, and program impediments.

  - Most significantly, they have overcome institutional biases to lead and foster a superior level of teamwork in a complex and technically demanding experimental program.
  - Collectively, they have earned the ARPA Award for Outstanding Performance by an Agent.

ARPA AWARD FOR OUTSTANDING PERFORMANCE BY AN AGENT

THE COMMAND AND CONTROL DIRECTORATE, ROME LABORATORY

- Accepting this Award: ROME LABORATORY Mr. John Graniero, (RL/C3).

- In 1989, the Command and Control Directorate of the Rome Laboratory approached ARPA with a suggestion for co-funding a new kind of program in knowledge-based planning and scheduling, *the DARPA-Rome Laboratory Planning Initiative ; now renamed the Rome Laboratory ARPA Planning Initiative* .

  - • Key elements of the program are tightly integrated research, demonstration, and user communities; metrics-based evaluation at all science and technology levels; and innovative technology transition mechanisms including co-funding partnerships between ARPA, Rome Laboratory, and recipient operational organizations.

- Rome Laboratory's outstanding technical leadership, management, innovativeness and creativity were all critically important to making the DRPI program a nationally recognized success.

  - • Rome Laboratory jumpstarted the ARPA program in 1989 and 1990 and worked with the ARPA PM's to build a critical mass of support in the technical community prior to ARPA's program approval.

- Rome Laboratory's timely support and teamwork directly shaped a new paradigm for software development - one that was battle tested in war.

  - • Critical support was provided to the 10 week Dynamic Analysis and Replanning Tool project at Scott AFB during the Gulf War.
  - • The result was credited by the Deputy SecDef, the Director of DDR&E, and the Commanders-in-Chief of the US European Command and the US Transportation Command with enabling the rapid construction of a new operational plan for deploying the 7th Corps from USEUCOM to Saudi Arabia.

- An April 1993 review of the Rome Laboratory ARPA Planning Initiative technology program and "concurrent engineering" planning model at the CINC's Conference were prioritized as the number one "must have" R&D program.

- Specific individuals who have provided KEY leadership are: Mr. Ray Urtz, Dr. Nort Fowler and Mr. Don Roberts.

ARPA AWARD FOR OUTSTANDING PERFORMANCE

BBN SYSTEMS AND TECHNOLOGIES CORPORATION &THE ISX CORPORATION

- Accepting this Award: BBN Dr. Ed Walker and Mr. Ted Kral
  ISX Although no representative from ISX could be with use tonight, I'd like to recognize them also.

- BBN and ISX submitted an original idea to be a part of the DARPA-Rome Laboratory ARPA Planning Initiative Team to serve as an advanced technology broker between the research community and the operational community.

  - • BBN/ISX has focused a large diverse research community on operationally challenging problems, and expedited the transition of research results into operational use.
  - • It is significant that the BBN/ISX team has been faithful to the original goal - brokering as opposed to internal technology development and transition.

- In addition, BBN/ISX has directly supported three operational demonstrations:

  - • the Dynamic Analysis and Replanning Tool (DART) - a crisis action planning tool that had a major impact in the Gulf War;
  - • the SRI Operations Crisis Action Planning prototype (SOCAP) - an employment planning tool prototyped at the US Central Command;
  - • the Theater Graphical Execution Toolkit (TARGET) - an integrated employment and deployment crisis response planning aid for the US Pacific Command.

- BBN/ISX improved and documented the original DART system and delivered the system to every joint planning staff during 1992. Eight CINCs sent unsolicited messages to the Chairman of the Joint Staff in August 1992 testifying that DART was one of their most important tools.

- This award is warranted because of the outstanding technical leadership and management by the BBN/ISX team and for the spirit of teamwork created in the larger Rome Laboratory ARPA community - and the evidence that their "brokering technology transition" model is highly effective - spanning the gap from laboratory to foxhole.

ARPA AWARD FOR OUTSTANDING TECHNICAL PERFORMANCE

EMS TECHNOLOGIES, INC.

- Accepting this Award: EMS Mr. Don Runyan, Program Manager.

- EMS has been a member of the Advanced Space Technology Program contractor team since 1990. During that time, they have established themselves as a top contractor for the provision of engineering design and analysis and product development.

  - In just three years, EMS has developed and tested two multiple beam antenna breadboards, each of which advanced the multiple beam antenna state-of-the-art at an amazingly low cost to the Government of only $750,000.
  - Their development of lightweight beamforming networks achieve a 10:1 weight reduction over existing MILSTAR feed networks.
  - In addition, EMS has demonstrated their dedication to ARPA and this technology bY cost-sharing the development of the Phase II antenna.

- The high-density multiple beam antenna technology that EMS has developed could be adapted to provide simultaneous multibeam operation with the potential to significantly impact future military satellite communications systems by enabling a single antenna to provide simultaneous low data rate and medium data rate beams to geographically dispersed areas.

  - The potential savings to the MILSATCOM architecture may approach one billion dollars while still satisfying user requirements.

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PLENARY SESSION — I

ARPA VISION SESSION — II
CHAIR: DR. H. LEE BUCHANAN

INFORMATION TECHNOLOGY SESSION — III
CHAIR: DR. DUANE A. ADAMS

KEYNOTE ADDRESS — K
HONORABLE WILLIAM J. PERRY, DEPUTY SECRETARY OF DEFENSE

MANUFACTURING TECHNOLOGIES SESSION — IV
CHAIR: DR. MICHAEL F. MCGRATH

FUTURE MILITARY TECHNOLOGIES SESSION — V
CHAIR: MR. RONALD D. MURPHY

Plenary Session I

I-A KEY PLENARY SPEAKER

CONGRESSMAN RON MACHTLEY

Plenary Speaker
Congressman Ronald Machtley

Tuesday, June 22, 1993
ARPA 16th Systems and Technology Symposium

Dr. Gary Denman, Director ARPA:

"The Congressman is in his third term serving the first congressional district of Rhode Island in the U.S. House. The Congressman was born and raised in Johnstown, Pennsylvania, the heart of bread and potatoes in Pennsylvania. He was an outstanding scholar and athlete in high school, which I think served him well in obtaining an appointment to the U.S. Naval Academy. So he's sort of in "home country" here at the Naval War College. He obtained a law degree from Suffolk College in 1978. The Congressman is a key member in the Arms Services Committee, and has been a good friend to the Department of Defense, in particular, supporting the programs at ARPA and other parts of the Department. I think he is also an especially good friend of U.S. industry and I believe he will talk to you in those terms today. He has done a great deal for the Newport area and Rhode Island, in particular, bringing defense business to this area and supporting quality programs here in Rhode Island. He has taken a leadership position on energy issues serving as co-chairman of New England Energy Congressional Caucus and he has pushed very hard for the conservation energy plan. Another important aspect of Congressman Machtley's background, he is a Captain in the Naval Reserve, which I think again holds him in good stead for being here with us this morning. So without further ado, I guess it's not Captain Machtley but rather it's the Honorable Ronald Machtley. Thank you for coming. "

Congressman Ronald Machtley:

"Thank you very much, Dr. Denman. I want to welcome all of you to Newport. This is my home, my adopted home. I hope you spend all of your money here. I hope you get down and eat some of our wonderful lobsters. If you are coming from warm climates, I hope you appreciate the coolness of our climate here and bring your families back many, many times. As was indicated in my bio, I am not a native of Rhode Island. I came here and fell in love with it, and I have stayed here and now represent it in Congress.

Congress is an interesting place to be these days. As all of you know reading in the newspapers, we are dealing with budget issues and we are dealing with a number of issues that affect you and your wallet. In fact, a lot of people out there are saying that no one is Congress is listening to what's going on out there. There may be some truth to that. And I was thinking of an idea that we should be listening to what's going on out there and several weeks ago I was talking to Jim Bunning. Some of you may know Jim Bunning from Connecticut. He was a great pitcher; some of you look old enough to remember when he was pitching. He was telling me that he was pitching against the Yankees one time and Bobby Richardson, the second baseman was up. When he threw the first fast ball, he heard a whistle from the first base coach, who was picking off the signals. He thought maybe it was coincidental, so he told the catcher he wanted a second fast ball. When he threw the second fast ball, the whistle again occurred and Richardson hit the ball into the outfield; it was caught and was an out. So Jim Bunning went off the mound, went over to the first base coach, and said, "If you are picking off my signals, if you whistle again on my fast ball, I'm going to hit the next batter and it's Mantle." Walked down to the plate and said, "Mantle, if the first base coach whistles, I'm going to hit you with the ball." Went back to the mound and the catcher called a fast ball. In his wind up, the first base coach whistled. Bunning said he just slipped his hands a little off the strings to an inside curve slider, hit Mantle right in the side.

Mantle later wrote in *Sports Illustrated* that was the closest he ever came to charging the pitcher on the mound. But he thought wisely and went to first base. Yogi Berra was the next batter up. Yogi got up to the plate and called out, "Hey Bunning, if there is a whistle, I'm not listening."

I like to talk about what you are doing and, hopefully, some of you may be listening. While I was in the Naval Academy, at chapel, we used to have these curved areas in the sanctuary and we called it Sleepy Hollow. It must be like those areas in the back of this room where everyone can just pass out and no one can see them, but I'll hopefully keep you alert enough throughout the next several minutes.

I like to think of ARPA, formerly DARPA, as sort of the Thomas Edison agency. Why do I say that? I say that because Thomas Edison had the uncanny ability to not only develop things, but to figure out how to use existing inventions and improve them and make them profitable in the civilian world. Thomas Edison had in his lifetime 1,093 patents. He was a brilliant person. Yet had only three months of formal education. Several years ago, I was at Fort Myer; if you ever get down to Fort Myer, if you are a scientist-engineer or just a person interested in history, go see Thomas Edison's laboratories there --they are fascinating. He walked out, his family just walked out and turned it over to Fort Myer. While I was there, I had the opportunity to pick up a book called "Uncommon Friends," by James Newton. It is about five people who somehow migrated down there: Firestone; Lindbergh; Henry Ford; Alexis Carroll, who was a Nobel Prize-winning surgeon; and Thomas Edison. They went there because of the uncanny ability of Thomas Edison: to draw out of them ideas, to perfect their inventions and to try to put into practical terms the ideas they had. Last year, it dawned on me as I was rereading this book, that James Newton might still be alive (the copyright is 1989). I tracked him down and talked to him about Thomas Edison. Here is a person who knew Thomas Edison in his life. He reaffirmed what my readings have showed me that this was an individual who could take an idea, follow it through and develop it and improve upon it. He took telephones and put the carbon transmitters in them. He took phonographs and improved them. He took motion pictures and improved them. He took even simple things that we use, like wax paper, and developed and improved them. And that's really what the essence of where we are going in today's world relative to DARPA and scientific and engineering technology. As I was watching my son play baseball last night, I was thinking about the field. It's a wonderful field and it wasn't always that way. I said to somebody, "Who really built this field?" (My son is in Little League.) He said there was one guy who was the hard-driving force. He had an idea and he followed through on it. That's really what I hope DARPA/ARPA, you all, are doing: Developing these ideas and following through with enormous persistence.

When we looked at the Desert Storm war and I went over there on the first freedom flight and we landed just after the war ended. It was a magnificent victory. All of America was proud of our soldiers, our sailors and our ability to win this war after the experts had told us in the Arms Services Committee that there would be, in minimum terms, 5,000 to 7,000 casualties and probably 10,000 to 15,000 casualties. We escaped with very little combat casualties in a war that ended in hours. People have asked well, "How did we do this?" I think there has been a great assumption that just occurred. Part of it was through the technology of the programs that then DARPA, now ARPA, had developed. The stealth technology that went in those F-117 fighter jets in the early parts of the raids -- that was part of the DARPA development programs. In fact, of the seven advanced technology ideas that were successful in our Desert Storm, six of them were developed at DARPA. But there were many others -- the GSP, which many of you are familiar with. A classmate and friend of mine was over there in charge of a battalion. I was curious because we are interested in using GSPs as a way of preventing ships from running aground out here in the harbor. And I said to him, "How is the GSP working?" And he said, "Oh just great. I can tell where I am within a few meters. The problem is telling where the rest of the world is." And it's been another example of technology has been developed through ARPA and through the ideas that they have.

We can't lose that technological edge. Whatever we do in the next decade, I can assure you that this institution is a memorial to the idea that peace is not eternal, that there will be a conflict. It was only because in this institution they did war games and understood the concepts of a Pacific theater war that we were successful in the Pacific theater. Just two years ago, we finished Desert Storm. Twenty-five years ago, my generation was either fighting in Vietnam or demonstrating against it. Fifty years ago, some of your generation was in the Korea conflict. One-third of the people who were on a ship transport going to the Inchon amphibious landing, had been in civilian clothes three weeks before. The military had been cut way back. Seventy-five years ago, we had several other conflicts. Almost every 25 years of this nation's history, we have had conflicts. There will be another conflict. It is not a question of whether or not there will be conflict. The question is who will be the adversaries and how will we be prepared. The next conflict for the United States will be a "come-as-you-are" war. There will be no chance to develop high computer technology. There will be no chance to build another submarine or to train another sergeant. We will take whatever we have on the shelf and go to war with it. And that means all of you who are developing technology must, in fact, move forward with the most important aspects of keeping up with the technology that is around the world. While the world is uncertain, it is clearly very dangerous. And much of the technology that is being developed in other parts of the world is, in fact, very competitive with the technology we have for military purposes.

What I hope is that as we are downsizing this budget, which is a great concern to me frankly, that we do not take away from the initiative as we are talking about dual-use, that we do not take away from the initiatives to do what the military's principle mission is: to fight wars and win. There is no second place when you are fighting a war. The only way we will be able to do that is to maintain our communications technology, our sonar and radar technologies, and our fire power technologies with people like yourselves, with DARPA and the organizations we have to maintain the technological edge that we have in our industry. There is the ability to take those ideas and transfer them into civilian technologies and civilian uses. In fact, we have seen much of that and that's why I refer to this as a "Thomas Edison agency." A program is being developed, with the assistance of ARPA, to develop micromachines so it can type gears and help improve the technology and make things miniaturized. That is something that, without ARPA, would not be developed and, frankly, without ARPA, would not, in fact, be available to the civilian market. Will we see a technology defense conversion where we are actually going to make swords into plow shares; the answer is probably "no". We are going to need a defense of this nation. Le' me give you an example of how difficult the problem is. In this state, we build Seawolf submarines. One Seawolf submarine to an electric boat represents a billion dollar industry. $ One billion. It is an actual $2 billion item. If we were to replace one Seawolf, which is a Fortune 500 company, it would take about, on today's market analysis, two hundred existing profitable small ventures. If you look at some of the 3 schools and ask them, as I have done, "how many start-ups do you need to have one successful profitable new venture?" The ratios can vary from 6:1 to 10:1. That means if you use the upper limit, you are using 2,000 new start-up companies to get 200 that are successful to replace one submarine manufacturer for one submarine. Very, very difficult.

This year we are going to reduce our defense budget. This week, as I go back as soon as I finish speaking here to Washington, we are going to be marking up at the House Arms Services Committee and we are going to reduce the defense budget probably about $11 to $12 billion, which is what the current Clinton budget is. We'll probably get through that. Last year, it was about $7 billion that we reduce the defense budget. But that is the seventh consecutive year of reducing the defense budget. The real concerns that I have are in 1996 and 1997, when we will reduce the defense budget not $11 billion, but $25 billion in 1996 and $36 billion in 1997. It's going to be very tough and one of the things that we are trying to make sure we do in the House Arms Services Committee is to keep the R&D moving, keep the technology moving. We are going to cut procurement. Procurement will be down 17 percent but we are going to keep R&D up. We

are hoping that there will be R&D development and we will put it on the shelf and say, "Go develop something else. And when that product is developed, put it on the shelf." All of these ideas are going to have to translate into civilian jobs because the current administration has taken the "D" off of DARPA and made it ARPA and they are insistent that we develop a dual-use technology. That's where the effort and energy is going to go and so we must always be mindful of trying to ensure that there is some civilian technology, as well as defense technology, available. I'm not sure how that is going to work; frankly, I'm skeptical. Again, I think the purpose of the military is to find technology that's going to make us better fighting warriors. If there is significant secondary applications to the civilian world that does not, in fact, give away our civilian technology, we ought to do that. That's where ARPA comes in. They ought to be able to have people who are developing the synergies between defense priorities and civilian technologies. You are obviously interested in how to get hold of the dollars, what to do, what is the mission, how do you get involved, how do you succeed. There is no easy answer. Just like Thomas Edison, just like Jim Bunning -- it takes a lot of hard work. I think we are going to see some remarkable technologies. When I started at the Naval Academy, we had a room filled with a computer and we were dealing in FORTRAN; Basic was just starting out. That was in the 1960s. Many of you were in the same types of engineering labs. Like me, you carried a slide rule on your belt. The company, I've understood, has gone bankrupt that made slide rules. If you have one at home, keep it. Some day you can show your grandchild how you used to compute logarithms.

I just bought a new laptop computer that has more power in it than the first computer I had when I was practicing law. It's got a flat screen that is very capable for making a presentation and has enormous potential future applications in the military. In fact, when people were in Desert Storm, they had miniaturized receivers and could receive up to 24 pages as the satellite went over and could get orders and communications; it was great. One of the problems with this laptop computer is that the flat screens are all made in Japan right now and it doesn't work if you have to look at it at an angle because you won't see a clear picture. We are going to have to improve on that technology. But I don't think we want to improve and have Japan develop and manufacture all of our flat, crystal screens. That means we have to get the startup industry going in this nation. We have to get a piece of that action. ARPA is probably going to be the lead in making sure that that happens as it has with miniaturization of computers, as it has in SEMI TECH and a lot of other consortiums. It's important that we develop a civilian product for the military and go the reverse. I suppose the message is we should also take some of our technology and put it into the civilian world. Certainly the computer industry is one of the most important industries in the nation and the world right now. What is most important is that we make sure we keep people whose brain power is essential to success gainfully employed by this country and make sure we are providing them opportunities. One of the things that Lester Throes in his book *Head to Head* points out is what has made this country great is that we have always had the top ten percent who have done the inventions; the problem is that today -- as evidenced by the fax, the microwave, the flat screen and the computer and many other technologies that we developed -- they are manufactured in other nations. In addition to you who are the entrepreneurial brains, we've got to make sure that we are developing a core of workers who have the capability to read a metric scale and read fundamental English and understand what it says, to take your product and utilize it.

Thomas Edison was a great, practical individual. He always took two of the best students from some of the graduate schools and brought them onboard as his personal assistants. James Newton tells a story of how he took two students from MIT who were outstanding mathematicians and said, "Your first project is to compute how much volume and weight of water would fill the light bulb." He gave them the light bulb which was flat on one side and elliptical on the other side, and they went off and worked on that project for about two weeks. They came back to Thomas Edison and said "We've got different answers, but we've both done it and we think we're both correct." Thomas Edison said, "Let me see what I can do." He weighed the light bulb, clipped off the metal portion, took an eyedropper and put water into the light bulb, put it on the scale;and subtracted the clipped off portion from the light bulb. That gave him the weight. He put

the water into a beaker and that gave him the volume. And he told these guys, "Now look, that took me about 30 minutes. Took you guys two weeks to figure out mathematically and you weren't as accurate as I was. Take the technology and education you have and put it to practical use."

That's the message I would like to leave with you. As we have tankers going up and down our coasts, we need the GPS to help them. We need supercomputers to figure out our mathematical models. We need the miniaturization of micromachines, we need SEMI TECH problems solved, we need lots of things in the industry. Don't be discouraged. And that's the final message.

While we are today reducing our defense budget -- all of you may be thinking that there is not a future for you -- remember, Thomas Edison worked for two years to figure out how to put a filament into a light bulb. It was Thomas Edison who said, "Success is one percent inspiration, 99 percent perspiration." It won't be easy in the next couple of years. I am absolutely convinced with people like yourselves, with ARPA and other people helping to developing this technology, the United States will be ready in the next 10, 15 or 20 years, whenever we are called, to meet whatever threat is out there with sophisticated technology that works.

Thank you and good luck."

I-B OVERVIEW OF ARPA MISSION

DR. GARY L. DENMAN

ARPA

ARPA Sixteenth Symposium
Naval War College

Dr. Gary L. Denman

22 June 1993

Dr. Gary Denman, Director, ARPA

Tuesday, June 22, 1993
ARPA 16th Systems and Technology Symposium

Dr. Gary Denman, Director ARPA:

It's useful to step back and ask yourself, "Do we have the foundation for a structure and mission for the Agency?" Amazingly enough, for a Government organization, we actually have a mission statement that actually describes very well what we are responsible for and as a foundation for moving to a post Cold War era within the Department.

In 1958, President Eisenhower established ARPA, largely in response to Sputnik, and felt that there was a grave need for an organization that would have the primary job, as a corporate organization to the Department, to focus on the question of technological surprise and technological superiority. ARPA has done very well over the years. There have been ups and downs and there have been changes, but I believe the Agency is alive and well and very healthy. We have the basic challenge to "pursue imaginative and innovative R&D projects". Obviously, that is in the eye of the beholder. I hope when you are done in the next three days that you will agree that the program we are doing and the program we are planning meets that criteria.

The word "projects" in that statement is an important word because one characteristic of ARPA has to do with its success -- besides having very talented people -- has to do with the ability that we can get in and out of technical areas. We are a projects agency; but compared to organizations that have infrastructure to maintain, our job of getting out of something is much, much easier. ARPA is not, as some have said, beholding to any institutions and, therefore, has freedom of action that is very different from other organizations.

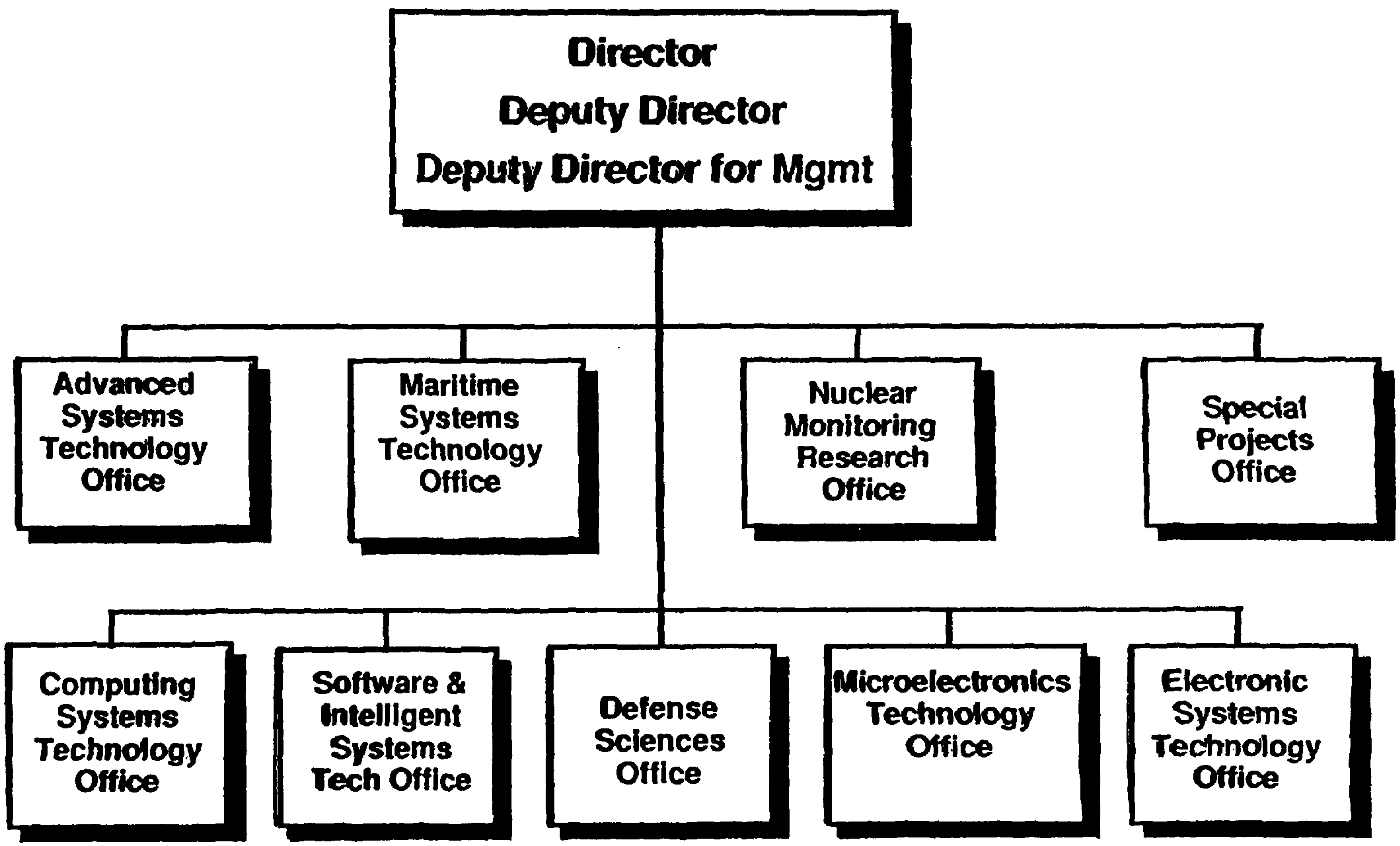
Another characteristic of the mission is that we span the spectrum of basic research to technology demonstration, that license to span that whole spectrum is critical to our success. The last line on the chart is the primary characteristics of ARPA that must be maintained, i.e., the idea of fundamental change, the idea of paradigm shifts (to use the jargon) -- not only in the technology, or in the military capability, but also in industrial capability. Those three things are the watch words as I look at the Agency.

Mission

- Central R&D Organization of the DoD
  - Maintain Technological Superiority
- Pursue Imaginative and Innovative R&D Projects
- Direct R&D Projects
  - Basic Research
  - Applied Development
  - Feasibility Demonstration for Improved Cost and Performance of Systems
- Cause Fundamental Change in Technology, Industrial Capability and Military Capability

We have nine offices in addition to the various support activities ranging from contracting to financial to personnel to legal and so forth. The nine organizations say a lot about the future. We reorganized a couple of years ago, but the organizational structure is still sound, with the top four boxes focused on customers and applications, and the bottom five focused on technology. It is a balanced organization in that context. You will hear essentially from all those offices during through the next two days.

ARPA Technical Organization



I know you are basically here to ask the question, "Where is the money and how do I get it?" So I want to show you some budget information. This is a collection of programs and subjective packaging of the program, and does not have any relationship to what you might read in the Congressional documentation that's public in terms of program elements and line items, and so forth. It is a mixed integration of that. I'll say more about this defense reinvestment dual-use line at the top. You all know much more about that in terms of the Technology Reinvestment Project. I don't want to overfocus on that; you can see that it is not dominating our program.

I think Congressman Machtley raised an important issue: we have the primary responsibility to ensure technological superiority for our military. We are not losing sight of that issue, and the budget outlined here shows that. On the other hand, the dual-use concept is a solid concept. The only difference between the top line and the rest of the budget is that the top line, Dual-Use, is a *requirement* of the programs; the rest of the Agency dual-use is a desirable *feature* to the programs. That's the way I look at the budget breakout and how I have tried to describe it to the Congress.

ARPA Budget

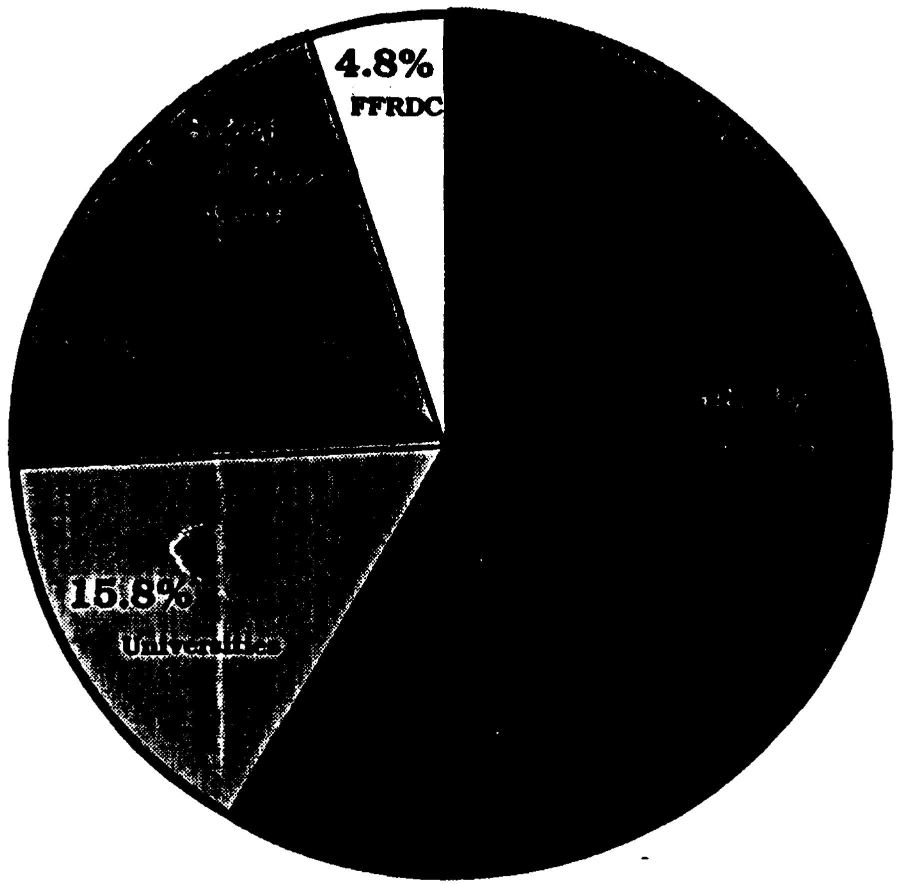
($ in millions)

PROGRAM AREA	FY 1993	FY 1994
Defense Reinvestment	562	324
Information Technology	337	388
Electronics Manufacturing	612	550
Systems Manufacturing	242	140
Materials Manufacturing	99	91
Military Systems	188	336
Innovative Technology	107	79
Special Access Programs	78	220
Agency Management	23	53
TOTAL	2249	2182

This chart summarizes how we spend the money. The item called "Not-for Profit" is basically driven by a lot of our partnerships, SEMI TECH and other non-profit institutions with which we do business. If you take the combination of the not-for-profit universities and industries, nearly 90 percent is going in that direction, with only a little over 10 percent going toward FFRDCs for various kinds of support, as well as program execution, mainly support, and some funding going on in some of the in-house laboratories of the military departments. This program remains, without danger, focused on industry.

Let me get into how we really sort out where we invest and what thought process is used as we decide where to invest; I hope out of that you go away with an understanding of how to sell ARPA. That is something I have observed, over the last two-and-a-half years that I have been here, that as industry comes in, it is all over the map in terms of how you excite ARPA about an area and so forth. Hopefully, this will help you in that regard.

ARPA Major Performers



This is specifically what I use as a mental checklist as we make our investment decisions. First and foremost, if ARPA doesn't have a talented Program Manager who really is plugged into the technology on a broad basis, then we should not be investing. Said in a positive way, a Program Manager is the key ingredient to any successful program at ARPA. Second is an involved customer; this has to do with the path to implementation question on the military side that I was speaking of. This is not a requirements process drill we go through at ARPA. This is a connection to the senior levels of the military departments and Joint Chiefs of Staff in terms of understanding where they are going and where their needs are going, and working with them to follow through on the ideas and develop the military concept of operation for whatever the investment we may be making. Being plugged in with the customer is a key factor.

Obviously, going back to the concept of fundamental change, we look for the unique technical ideas, not for the "me too" technical ideas. Military context for an idea is coupled to a customer perspective, but is also very key to focus on, particularly as we move from technology development to the military applications part of the program, to understand the military context of what we are developing.

Another key factor: "Is the industry able and ready to execute the program?" That particular item in the past has been fairly easy. Today, that is getting to be a harder question as the industrial base reshapes as you and your companies change, downsize and shift. It gets more difficult for us to predict who's going to be in a particular business in five years. That's critical. More often than not, as I see large investments in technology that don't get implemented, it is because industry has changed its business strategy in the midstream of the program and decided not to pursue a particular technology in terms of moving to product. That's why it is required that we stay very close to each other -- that we sustain a close relationship and dialogue over where you are going in your business plans coupled to where we are going.

Sufficient dollars to drive it to conclusion goes without saying; and that's one of the unique features of ARPA. We do our best not to underfund a particular technology, and if we can't fully fund or get the funding to the levels to what it takes to bring it through, then we shouldn't start programs. That's probably the most important chart I want to talk to you about today, but I would like to shift now to discussion of some of the current drivers -- things that are driving us to our decisions -- that I hope you find helpful.

ARPA Investment Criteria

- TALENTED PROGRAM MANAGER
  - Understands technology, application and players
- INVOLVED CUSTOMER
  - Shares vision (senior level entry point)
  - Capable of follow through
- UNIQUE TECHNICAL IDEA
  - Can create fundamental change
- MILITARY CONTEXT FOR IDEA
- INDUSTRY (UNIVERSITY) TO EXECUTE
- SUFFICIENT DOLLARS TO DRIVE TO CONCLUSION

As I have just said, unequivocally, a clear military need in all the programs in the key factor. That's unchanged and that will not change.

I enjoyed Congressman Machtley's corollary to Thomas Edison's approach to technology because I certainly agree with that. I have never thought of it in terms of Edisonian perspectives; i.e., focus on the past to making products available. That is something that ARPA must sustain a vision as contrasted to a general statement to move the technology forward or to invest in resurge or just to invest in good ideas. All of those are important, but if we lose sight of sustaining a path of product availability, we lose a key characteristic of ARPA. That path can be to commercial products, or to military products.

Dual-use is in the best interest in the Department of Defense, and has to do with affordability. If we, in fact, sustain the approach of having dominantly military-unique components and products (it is not industry's fault, industry has been incentivized to do precisely exactly that), we will not be able to afford the military the American public expects from us. That's my vision of what dual-use means. It is in the self-interest of national security. It is not fundamentally an industrial policy issue; rather, it is a necessity that we have to look at -- to draw to the maximum extent possible from the commercial base in this country and, in some cases, worldwide. That's the strategy we have to be on. You will hear those kinds of things from Bill Perry when he talks to you tomorrow.

Another characteristic of ARPA is our ability to dialogue with you, the industry, in allowing goals and, therefore, leveraging each other in the investment. Finally, I think we are exploring some business arrangements that are unique and new, and I find the most excitement is in the unique business arrangements primarily driven by this thing called "agreements" -- which I won't go into detail today. Basically, it gives us the flexibility to sit down at the table and negotiate in somewhat of the manner you would negotiate a commercial contract.

Program Characteristics

- Clear Military Need
- Path to Product Availability
  - Commercial
  - Military
- Highly Leveraged with Industry
- Tailored Business Arrangements
  - Agreements vs Contracts and Grants
  - Partnerships

People talk about a military technology revolution that is underway. I personally believe that, in fact, is true. It is all based on information technology, electronics technology. If you think of it has the perfect knowledge of what's over the hill, that's the military technology revolution at least embodied in one part. I believe that we are moving in that direction and that we are the leading edge of this revolution. We don't know where that is going to take us, but I believe it is going to shape military strategy in a dramatic way, just as nuclear weapons did in the past. Some would say that's a gross overstatement; I believe it to be true and that is why I so strongly support our sustained investment in information technologies.

Another thing that is absolutely driving us now: it is very clear that affordability is going to shape our future military weapon decisions in ways that we've only begun to understand. Therefore, working affordability at the beginning of technology investments is more critical as time moves on. ARPA is well positioned with that. As you know, over the last three or four years, there have been some dramatic shifts at ARPA relative to investment and manufacturing technology, which is quite a change over the last three years.

Of the key issues that will shape and are very critical to the kinds of warfare in which we are likely to engage in the future, the whole area of situation awareness and precision attack will shape our military strategies very dramatically to the future. A lot of things are behind that statement; it means a lot of things ranging from some of our planning initiatives to a lot of things as you move through our programs and you might want to think about that as you listen to some of the briefings.

Finally, this concept of integration of the defense and commercial base, both technology base and production base, is a national priority. We must do it. My role is primary in trying to do that in shaping the technology base. I think equally important as we move forward and you see some of things going on in acquisition reform in the Department will move in this direction to accomplish that in the production base as well.

ARPA Program Drivers

- Information and Electronics Technology Revolution Forms the Basis for the Military Technology Revolution
- Affordability will Dictate Technology Implementation
- Situation Awareness and Precision Attack will Continue to Shape Military Strategy
- Integration of Defense and Commercial Technology (and Production) Base is a National Priority

Some of the external things that are driving our program that make it very difficult when you have external drivers of this type, are plans that are unchanging. Our plans are changing dramatically over the coming year and some of the external things that are driving that are restructuring in the industrial base, the concept of conversion. Congressman Machtley said it very well: we are not going from weapons to plow shares nor our aircraft industry, as some have said, converting to making bicycles. That is utter nonsense. However, there are some levels of industry that will successfully convert. Those levels tend to be the second, third tier, first tier subcontractors. The medium and small size companies that are more agile and, in many cases, already have knowledge and are serving commercial markets. Those are the shifts that will be most important. They tend to be at the component supply level for the Department, and I think you will see ARPA focusing a great deal on those kinds of companies in the context of integration of the military and commercial base.

There is obviously a lot going on with respect to the economical and technological policies, primarily out of the White House. We have to track that very closely. It is evolving and as it evolves, it bodes well, not only for ARPA, but for other institutions in the Government, and I look forward to working in collaboration with many of those institutions.

Another shift that is going on and is an external driver for our programs as to do with role of the intelligence community in supporting military operations. We are going to see in the next two years dramatic shifts in that regard, and that will cause some reshaping of the ARPA program as we try to support that shift. Obviously a challenge that is just unfolding is the contraction of the fore-structure. I believe the ARPA program must respond to that contraction as it unfolds through the bottom-up review process that is going on today.

External Program Drivers

- Industrial Base Structuring
  - Conversion
  - Downsizing
- Economic and Technology Policies
- Intelligence Community Support to Military Operations
- Military Force Structure Contradiction

Let me shift now to describe some of our programs and give you a sense of where I see the investment emphasis in the near-term (over the next two or three years). I have just described our commitment to information technologies and, hopefully I have described my rationalization for that, and electronic technologies, as unwavering. This represents over half of the Agency, over $1 billion in terms of investment annually in these areas. Obviously, we are still connected to and managing the SEMI TECH program; we expect that to continue on more of a project basis rather than on the previous basis of broad-based investment. There are incredibly, exciting things going on in the electronic packaging program that essentially will provide a shift of the equivalent of one generation of micro-electronrics, and with a whole lot less investment.

The high-definition displays is a critical product-defining technology, and we are sustaining our support for that. That is a very controversial subject. It has become the pilot project for shaping industrial or technology policy; you will see a lot unfold in that program over the coming year.

High-performance computing is one of our largest programs. It is, s you know, designed to cause a fundamental shift from vector computing to massively parallel computing, doing that in a scalable fashion. We plan to continue that program at well over $200 million a year in those investments and with some shift toward enabling applications as contrasting to enabling the concept, you will see more of an application shift in that program than you have in the past.

The networking technology is like being on the back end of a wild dog being jerked around because that is moving so fast the industry is restructuring at a pace that I can't even begin to keep track of. You read in the *Post* or the *Journal* every day about another deal being struck with respect to networking, and networking technologies between the telecoms and cable companies is kind of all over the place. ARPA can provide some leadership, staying one generation ahead of where the telecom basically are. That is our role and that's the role we will continue to play.

We are putting in some incredibly high performance testbeds at the present time and plan to continue that sort of investment. We are investing strongly in some areas that have to do with "connecting the fiber," if you will, in photonics and optical electronics.

Software remains the Archille's heel of this military technology revolution I described. We have no silver bullets at the present time. It's an absolutely key area that we must sustain our investments and we plan to do so.

You are going to see more and more applications of information technology in various Agency programs. We are doing a great deal in planning systems: command and control, crisis management and we are going to see more. We are looking at the medical area and various areas in that regard.

I think we have only begun to understand what we can do with microminiature systems ranging from battlefield management applications, personnel performance, monitor applications, distributed sensors, etc. The opportunities abound to exploit all of this technology. Perhaps power management remains the most difficult technical challenge in that regard.

ARPA Program Thrusts

INFORMATION AND ELECTRONICS TECHNOLOGIES

- Microelectronics Manufacturing
- Electronic Packaging Technology
- High Definition Displays
- High Performance Computing
- Advanced Network Technologies
- *Software Engineering and Software Systems*
- Integrated Information Applications

MICRO - MINIATURE SYSTEMS

- Mobile Communications
- Distributed Sensors
- Situation Monitors

We are not a broad-based investor in materials technology, but what you are going to see over the next year is a sustained look at the high-temperature composites business as well as the low-cost manufacturing business for conventional composites (as a major emphasis) and a continuation in our work in various exotic electronic materials: high-temperature superconducting, diamond films, etc. Manufacturing applications relates to the whole process of design and manufacturing of systems and its integration. Some of the strategies include focusing on decoupling costs and volume, classic cost and volume relationships; it involves concepts of flexible manufacturing. One of the areas we should put some emphasis on is the assembly process. We are doing quite a bit in the physical processes in manufacturing. I believe we need to look at the assembly process stronger than we have.

ARPA Program Thrusts (Con't)

MATERIALS TECHNOLOGIES

- High Temperature Composites
- Low Cost Manufacturing
- Electronic Materials

MANUFACTURING APPLICATIONS

- Design-Manufacturing Integration
- Decouple Cost - Volume
  - Flexible
  - Lean
  - Assembly Processes

These are some military applications: precision attack capabilities (which couples with the surveillance and targeting kinds of sensors), battlefield management situation awareness, the literal waters. We are continuing to look very hard at ship systems design and construction. The contingency vehicle business is, for contingency forces, one on which we should sustain our emphasis. We have to develop a lighter effective forces if we expect to have a responsive army to crisis situations. And finally, one that we all have to think clearly about is the non-proliferation business. This is one thing that Secretary Aspin is very committed to. It is probably also the most challenging problem we face. We've done in ARPA a good job in nuclear counterproliferation monitoring kind of business. How we extend that to other threats in the Cambio areas is a major challenge that I don't have answers today. I only have questions, but you will see us increasing our focus on that military need.

ARPA Program Thrusts (Con't)

MILITARY APPLICATIONS

- Advanced Surveillance and Targeting Sensors
- Precision Attack Capabilities
- Situation Awareness
- Literal Water Submarine Technologies
- Ship Systems Design/Construction
- Light/Mobile Contingency Vehicles
- Non-Proliferation Technologies

The Training and Education Area. This is not a complete list. If you don't see your favorite future thing here, don't get excited. There is, in fact, a longer list we are working on. What we need to think through carefully is the training and education technology business -- how we can improve the effectiveness of our forces -- as well as, perhaps, create some dual-use opportunities. Obviously the simulation business is something that ARPA has been remains committed to, application of simulation technology and computer technology is what I'm thinking when I use those terms. Environmental technology is only going to increase as time moves on in the Department, both in the prevention area i.e., environmentally safe manufacturing which we are already investing in. Monitoring, applying some of our advanced sensors to monitoring environmental issues and clean up processes. We are not doing a great deal; we have a couple of innovative things right now. You may see more. I believe the whole area of optics is something, I am speaking all the way from the micro-optics of the photonics area all the way through physical optics is something that is going to become more and more important. In an area that I cannot tell you where exactly we are going right now but the whole broad based vehicle technology business is something we are having a lot of discussions about, don't read this that we are going to start a massive program in electric vehicles though, that is still under a great deal of discussion. "

Potential New Investment Areas

- TRAINING AND EDUCATION TECHNOLOGY
- ENVIRONMENTAL TECHNOLOGIES
  - Prevention (Manufacturing)
  - Monitoring
  - Clean-Up
- OPTICS MANUFACTURING
- VEHICLE TECHNOLOGIES

I-C Dual Use Technologies

Dr. H. Lee Buchanan

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Aug 2, 1993

MEMORANDUM FOR DSO - BUCHANAN

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

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Dr. H. Lee Buchanan, III
Director, ARPA Defense Sciences Offices

"Dual-Use Technologies"
Tuesday, June 22, 1993
ARPA 16th Systems and Technology Symposium

Dr. H. Lee Buchanan, III:

(First Slide) I am going to try to motivate a little bit more expansively some of the key items that Gary just addressed. You will recall that over the past several years, we were in something called "the Cold War." It's over, we won. It was, you will recall, much a war of attrition, and the measure of effectiveness of the system that we rose to meet the challenge was largely the extent that it was never used. And that is right. As a matter of fact, it was not much used in latter years. The nuclear arsenal, in particular, served its purpose just right, and we won. Thank goodness. That puts us, however, in an interesting spot. We in the Department of Defense find ourselves between the proverbial rock and hard place. The rock is that all of those threats and the missions have changed. They haven't gone away; they've changed. The world is still very much a dangerous place. It's obvious if you look at any newscast. There are people out there intent on doing us misdeeds. There is no less a requirement for a defense than there has ever been; however, the one that we built up in the process of this war of attrition against a foe that has diminished is not necessarily the right force for the threat that is now apparent. The hard place, on the other hand, is that there is no money. The budgets are surely coming down and it is as it should be, and there is little resolve on the part of the American people and the Congress that represents them to reconstitute -- that is an old term that has a dual-use meaning -- a force in a different direction out of a large residue that we have already. That's the rock and that's the hard place.

(Second slide) There are two major problems that are obvious to us all. First, we have now as a function of this Cold War of attrition two separate industrial bases: one commercial and one military (or defense). They are very different. They differ in some obvious ways that I list here and not so obvious ways that you know yourself. Defense is, of course, driven by the threat where the threat moves quicker than the industry can respond; you find yourself the rock-and-a-hard-place problem that we are now. Industry, on the other hand, moves towards opportunities. They are always looking ahead of the current picture to make sure that the direction in which they are moving and the speed corresponds with the opportunity that is likely to arise. Two very different ways of looking at two very different problems.

Defense, as you know quite well, is bounded by a set of rules and regulations that are meant to ensure competition and fairness in a situation where there is only one customer. You know it as the FAR. Industry, on the other hand, very much responds to the marketplace. When two companies in an industrial format want to do a deal, they often sit down across a table with more or less a clean sheet and try to do those things that make sense. While the FAR was certainly instituted as a set of rules that make sense, the changes that accrue over time make that sense sometimes more opaque than at other times. Defense is very much motivated by desire to be ready at a moment's notice in a place not known to do a job that they cannot always rehearse for. It's very much a stockpile mentality. You have a standing army that has standing equipment that's ready at a moment's notice to go and defend the country. Industry, on the other hand, responds in a very different way. More so in recent years, it has taken the notion of a "just in time" mentality. I don't want to have large stockpiles of raw materials; I want those raw materials to be ready to be instituted into products *only* when I need them, not a lot before and certainly not a lot after. A very different way of looking at a very different problem. The two are not similar and that accounts in great measure for their separateness, both in the past and in the present, and that's too bad.

The second problem is really one that accrues to both of those sides: a sluggishness on productizing new technologies when they become apparent. I choose not to use the phrase "tech transfer" because I think that connotes something very much more simple than anything I've ever seen in operation. The insertion of technologies into products is very much an intimate body contact sport where it is very difficult to see the actual transfer taking place. It's very difficult to see who is pushing on whom in order to get these technologies in place. It's more idiomatic or osmotic, and in most cases it's very, very sluggish. Certainly more so than our competitors and that's a problem. In short, we need to somehow solve both of these because we cannot afford either problem to persist any longer. You will see, I hope, in what I say this morning and what the Agency does in the future, that we are very mindful of both of these problems and mindful of the fact that we need to do something very dramatic as a country to solve them.

(Third slide) What to do? Well, as Gary mentioned there are lots of ways to "skin this cat." You will hear Dr. Perry tomorrow, I hope, talk about procurement reform. I know of no one more interested, more energetic and more competent to do something about that than Dr. Perry. It is a mammoth job, and we are all going to help him in every way we can. All of these issues are well known to you. The huge number of specifications, the huge amount of cost accounting, the oversight given by the Department on contractors -- all of these things are impediments to actual productization of technologies and the institution of goods for the military. We will have to do some measure of procurement reform. I don't know that ARPA will be central in that role. We are not a policy agency. We will certainly seek to help in that role and I will assume that we can make some real contribution there.

There is a problem as well with manufacturing because, as you well know, the Department of Defense buys things in quantities that aren't like 10^{10} or 10^9. For those of you who have had economics more recently, will remember that there is a cost curve that says the more you make of stuff, the less that stuff will cost due to the distribution of cost along a greater number of items. That price cost curve will have to be flattened if we are able to afford defense material, and the flattening of that curve can only be done in ways that institute new manufacturing methods. As a department and agency, we are constantly looking across the board for manufacturing techniques, technologies and methodologies that will allow that curve to be flat so we can buy a few number of things at a price that is more indicative of a larger demand. Very much a technology-driven effort. You may know of some of the efforts underway. I give as an example the MANTECH program.

There is a third approach that says there must be new ways of doing business that will attack this problem. You heard Gary mention a number of them. I do hear consortia and partnerships have been "an arrow in our quiver" at ARPA for the last three years. We see that they have great benefits; they are not at all without pain and some suffering, and we are very much, both in the Government and industrial side, learning to maneuver in this new world.

There is a fourth approach -- one that I would like to spend most of my time talking about this morning -- it goes under the name "dual-use," which simply means to recognize that another way to get goods at a price consistent with a high demand is to buy those goods that have high demand. Where you can do it and where it is possible, you want to always acquire technologies and materials from a larger marketplace. Even to the extent of instigating a marketplace in order to buy those goods and services later. That's the inherent notion of dual-use. It is *not* a conversion from military to commercial; it is a *merging* of the two in ways that have advantage to DoD in its current situation of new challenges with less money.

(Fourth slide) This is a very simple chart that illustrates that point again. If I had drawn this chart as of several years ago, there would be very little overlap between those two ovals. The notion now is to try to push them together even more than I have shown such that the overlapping center

ground, which I call "dual-us," is to the greatest leverage of both the commercial and the defense side of the equation. Obviously, as products become more and more specialized for either customer, the markets will become exclusive from one to the other. Where you can recognize leverages and situations that you can build on, that's exactly what you want to do as a new strategy and is the focus of our dual-use programs. "Spin-off" refers to those technologies that defense and industry together would develop and mature in a direction of a commercial product to the point that it will become viable as a commercial product. "Spin-on" would be those technologies that defense and commercial industry together would develop in a direction of a military product to the point that it is established viable as that military product.

I have chosen those words in a way that does not put the DoD in the business of venture capitalizing commercial industry and, in fact, you will see that as a threat that goes through the TRP as well. These are very much technologies that would be developed where both sides of the equations are served, instead of only one. I said I would not use the phrase "tech transfer" and would also not use the phrase "defense conversion" because what is more appropriate here is "defense merging" rather than conversion. In fact, since I made a point of saying how separate defense and commercial markets are, I imagine that much of defense industry will be unable to convert in a simple sense into something civilian.

Recently I spent some time with a member of the new Russian parliament. We had a chat for about two hours through an interpreter. He was in this country to find out what he could do to convert, and it was perfectly obvious that conversion in his sense is going to be even more severe than in ours. But the problem is really the same. We have developed an optimized system in both cases and it will certainly be suboptimal if it gets torqued into something else. It is a very difficult problem, one that will require some pretty innovative approaches.

(Fifth slide) Let me now make some observations. I don't think it will stretch your credibility to know that much, if not most, of what ARPA is now doing is already dual-use. In fact, I have seen an informed estimate that said a full 80 percent of the ARPA repertoire is dual-use in the sense that these are technologies that have defense application and a potential for commercial viability. This is not new; this is a rather traditional fraction. The morphing of DARPA into ARPA really won't be that great a difference. It is still true, for instance, and I see no diminishing of this, that our military investment will continue to be driven by military need. The difference is that we, as a department and certainly as an agency, must now be mindful of the existence or lack of existence of a commercial potential because that will signal whether or not a technology will be available to us at a cost that we can afford. Affordability is really the driver here. Affordability, as a result of dual-use, is what is driving much, if not, most of what you see.

It is important for us at ARPA to continue to have in mind the difference between our customer and our consumer. I am on the technology side of the Agency and I have said in the past that my customer is not the Department of Defense. My *customer* is industry. My *consumer* is the Department of Defense. (I can say that because my technologies are more at the component level.) DoD is not normally in the business of buying a pound of composites or a transistor or two, except as spare parts. They want those composites and electronics integrated into systems. In order for me to get a technology into a system, it has to go through somebody who's going to put it into that system, and that is why I say that industry, you, are my customer. Only if I can get a technology inserted into you, will I get it available as a piece, an item, that is going to be purchasable by the Department of Defense. This is not a new idea; only a re-recognition of that same idea, and component technology seemed to be easiest to do this with. As a matter over fact, it is almost a square law where the difficulty of inserting new technologies goes as one over their size squared. It is very easy to insert a new chip with a new function (not very easy), but it is easy to insert a small chip into a system where the peripheral parts of that system can adapt. It is very difficult to insert materials technology, for instance, where the item, the actual thing that is constructed, is very large. That doesn't mean we don't have to work at it; we have to work at it always. We have

to work particularly hard where technology is going to have a pervasive impact. Because there is where you see cycle times of seven or eight years, in the case of materials, where it is only 18 months in the case of microelectronics.

What may be new to many of you, at least in the dual-use sense, is a notion that we recognize (in the Department of Defense and certainly at ARPA) that we need to have a relationship with you, my customer, that is very much more partner-like, very much more collaborative where a deal (in our case for technology development or technology insertion) has every bit as much of our own self-interest on the table as in our own risk. We will be looking to involve you, the producer, in everything we do in a bit of a different flavor. As you will see later in the TRP, for instance, that integration is explicit because, in fact, you will be required to put up half the money. Therefore, your interest is going to be assured. As a matter of fact, we are going to put you in a position of risk precisely so that if a development "goes south" for some reason, you will be perhaps the most interested in terminating an effort rather than us because it is no longer serving your self-interest. We are going to depend on you having our own self-interest at heart.

(Sixth slide) It is pretty easy to come up with a very long list of examples of dual-use technologies. I put this up there and will not talk about any of them. That really is the function of the rest of this seminar. In each case, you can easily point to a defense applicability and a commercial viability at some level. Where they diverge, then our partnership must necessarily end, but that altitude where that divergence occurs is often quite close to the marketplace; microelectronics, for example. What you do not see up here are things like sporting goods, kitchen appliances or astronomy. Those are not dual-use items and will receive less emphasis from the Department of Defense. The point here is that there really is a demarcation and there is no intent, at least that I am aware of, to send the Department of Defense into large commercial endeavors that are uniquely and specifically commercial.

(Seventh slide) Let me talk about the specific impediments that I see and what we are trying to do about some of them. This is a list of systemic obstacles with which I am sure you are familiar. I've written no market demand, but what that refers to is something a little bit more specific; it refers to the notion that we in the Department of Defense are asking you to do something kind of difficult. We want just a few of an item and we don't want to pay a big profit. Normally what attracts you to a business is to be able to do a little bit of profit on a large volume of thing, or a large amount of profit on a few of the thing. We are asking you to do neither of those, and it's going to be difficult to keep our industrial base competent in many of the technologies that we need. That induces us to try to identify those technologies we need to incorporate that either have, or we can stimulate, a commercial potential. Again, inherently, a dual-use approach, a bit different from previous years.

Unattractive contracting practices are endemic. I won't dwell on them. You heard Gary talk about other transaction authority. I think that is the first of many required breakthroughs in the acquisition system. It is not a panacea. There are situations that just do not tolerate this kind of new instrument. As a matter of fact, the law states quite explicitly that another transaction may not be used where a contract or a grant is the appropriate instrument. Much discussion over the previous couple of years has been over where that line can be placed, where the appropriateness goes from one to another. Nevertheless, it represents a new opportunity to do things in a very new way, to get us out of the mindset that says there is a set of rules, it's in stone, it's immutable, and therefore, we have to put up with it. Where it makes sense, we can use these new authorities and you will see a greater pressure to move in that direction.

Lack of capital. The most frequent complaint I hear with respect to the TRP is that those programs do not take products far enough into the marketplace -- that is exactly right. As I mentioned, the Department of Defense is not currently in the venture capital business. The TRP can and should be used to alleviate much of the anxiety, at least early in technology development. Cost-sharing, at some fraction, is a way to do that where much of the financial risk and financial burden is taken on by the Department of Defense with the understanding that its purposes are being served as well. Remember: both at risk, both with self-interest. There are some issues that go along with this as well and the issue may be the percentage of cost-sharing or whether that cost-sharing is in kind or not. You know that, within the TRP, we are required and bound to enforce a 50 percent cost-sharing. We are allowed to accept, in kind, contributions as part of the cost-share, but everybody must recognize that the equality of that in kind is very much at issue. Again, it goes back to the notion that I'm trying to put you at risk in every interaction so that you have as much to gain by a success as I do so I have your interest and enthusiasm.

(Eighth slide) There are some sociological obstacles, as well, and I am sure that it is kind of funny for those of you with degrees in sociology to hear a physicist talk about sociology. I apologize, I mean no offense, but this is the kind of thing that goes on between the ears rather than between the covers of books of regulations. Several years ago, I had a particular technological success in my office and it happened to be at a university. I was very excited about its potentials and met with the performer of the work. We put the technology on a very large table and invited industry to come in and view it, and they were equally impressed. At the end of the day, they were very congratulatory and I asked the question, "Who's going to take this technology and do something with it?" Everybody sat on their hands. I waited a long time, asked the question again and nobody moved. I went around and said, "What's the problem? Why aren't you taking it?" I got lots of answers: "It's not developed enough." "It's not mature enough." "It's too risky." "It does not fit into my product line." "I don't have any capital, etc." I went out with each company representative and bought two or three beers. The notion was, "OK, come clean. What's the problem?" Once I got to the bottom of it, I found that the real reason was that because I offered it to some other guys, they didn't want it. Unless there is some exclusivity that goes along with the deal, it is very difficult to get that technology transfer. It was a revelation to me, and it accounts for our approach in the TRP that we hope to give the intellectual property rights to the performer so as to give that performer an interest and a stake to take that technology and make it into a product.

There is a technology learning curve -- the bathtub of technology development -- where technologies are very difficult to incorporate because it is too hard to understand. "I have a technology, I'm confident in it, I understand its features, its nuances and I just don't have time to learn about something new." There are ways we can help this and numerical simulation is one of those. It is the focus of quite a large program at ARPA that helps to understand the performance of new technologies and new situations before one bends any metal and builds any systems. Thereby, hopefully, gaining the confidence, the visceral feeling, in the part of the user that those technologies can be incorporated. We are financing something called "insertion programs." These are most often at the component level and the message is really simply this: we do little development in these programs in a technological sense. These are programs that are intent on getting technologies into products, even where the Government has to defray the risk of incorporating those technologies and those products. The first of these programs was the gallium arsenide insertion program. We have other insertion programs in optical-electronics, and in advanced ceramics, at the component level where we are actually paying people to incorporate these technologies in existing or planned products.

Tech transfer. Not effective because of interactions between institutions, between the parts of a single institution. I once had dinner with the chief scientist of a large corporation with a lot of divisions, and he was trying to make some transitions between the various parts of his company and having almost no luck. He concluded that the reason was because he had vice presidents. The issue is that when you have a vice president that stands over a large sector of the company, that

vice president has, in his incentive, a great motivation to work within his own division. There are few incentives to work outside that division, even where there is mutual benefit. Psychological/sociological problem. So he came up with a fix: joint development projects between the members of the divisions administered by someone completely out of the company. I asked, "Who do you get to do these things?" and he said, "University professors." Now, what is wrong with this picture? A large company brings a university professor in to run a project that is totally staffed by members of that company. He said, "It really doesn't matter who comes in as long as that person, that manager, is not affiliated with one division or the other." (Turns out university professors work a little cheaper.) That was a mean by which he could broker technology from one sector into another.

We are trying to do the same thing. We at ARPA are trying to broker relationships in which we have an advantage of neutrality, where we can step back and say, "OK, we have only to gain by you two getting together. Let us help 'straighten out some wrinkles' and 'iron across some seams." I think we have been very successful in that. Certainly, the experiences we have had over the last two years are consortia efforts (which started in FY91 and FY92) and are very much typical in that sort of interaction. My prediction when we got into that business was that the real contention was going to be between members of industry as a group and the Government as a group. As it turns out that wasn't the contention at all. The contention was between the members of the team and each other, and we could perform within the Government the very definite brokering role that we've tried to perpetuate.

Perceived risk. This is along the lines of an insertion kind of approach where we would hope to take a technology that has been shown effective at the fundamental level and do prototypes to demonstrate the efficacy of that technology in a real-world environment to identify those unknown "unknowns" that invariably come up when a new technology comes around.

Those are the kinds of innovative approaches I think you will see more of as time goes on and that we think are going to be very influential.

(Ninth slide) There is a seamless transition from one to another. Where one has to characterize between the two approaches, I would offer, that this is a very simple-minded and misleading dichotomy between the two. In the traditional approach, the potential for a technology to give a defense product was exclusive. It is still very, very important, but we always have to keep an eye to the market, what the market will sustain and what the market will stimulate. In the old days, we used to do projects exclusively by contract or grant, which meant that the Government ran the program and the performer delivered what was in the contract. Now you are going to see very much more a partnership, or a cooperative air or atmosphere. I think that is very healthy. It will not be pervasive and it shouldn't be. We are not going to change everybody into this mode of business. What I'm advocating is that we recognize those places where a partnership or consortia are effective and explore those places rather than ignore them.

Risk has always bee tolerated in ARPA programs and that will never go away. In dual-use, however, there is more than ARPA's self-interest on the table; your self-interest is on the table and, as a partner, you are going to be less tolerant than we are. I think the results will be programs that, as a whole, less risky, simply because we are looking for a real product to arise that you can incorporate into your product line.

I've talked about cost-sharing as a new approach for incorporating your enthusiasms and your risk to the table. We have a new emphasis and we are learning very fast what it means to have a product plan. I did not put up a business plan because a business plan has too much overtones of a purely commercial situation. We are now coming to grips with the notion that it is really not sufficient to develop a technology, put it on the shelf in a hardware store and wait for

system incorporators to grab all these technologies and put them in a shopping bag. You come back and see lots of shelves with a lot of technologies on them. Unless we are very active in getting these technologies into products, we won't be successful. You are going to see a lot of emphasis on that.

(Tenth slide) You did not really expect me to come here and not talk about TRP at all. This is the token one veiwgraph. It is merely meant to convey to you that, if you read that mission, no where in that mission do we talk about defense conversion. We are talking about a transition from one state of affairs that has been successful to another state of affairs that I hope will be just as successful. Getting from here to there will require some effort, hard work and, in some cases, anxiety. What we are trying to do is to stimulate a merger of the two industrial bases into a single industrial base capable of delivering both commercial goods, and affordable military goods, as well as an enhancement of the rate at which technology makes its way into products.

(Eleventh slide) The question was asked from someone, what the relationship was between the NIST program and the ARPA program. The quality of this viewgraph is not very good. It was drawn up by George Oriano, who is the Director of the ATP program. This is his view and by the way, my view of the relationship to TRP and all of the other things going on. These are a bit unconventional axes. The lower axis, economic competitiveness (to make money) all the way to the left, as an extreme. The military effectiveness is all the way to the right. Dual-use, therefore, must be somewhere in the middle. You can make up your own units. On the vertical axis, what we tried to depict is the extent to which the Government intervenes in the conduct of a program. Obviously, where that Government leadership is least then it is an industrially driven program. Where the Government is interested most is at the top, and in the middle somewhere are these partnerships and consortia that I have been talking about.

The traditional DoD tech base, and I include ARPA in much of that, is in the far right corner. That is clearly the Government interested in providing for technologies for products that the Government will buy. The chief discriminate is military effectiveness, all the way to the right. ATP puts itself in the lower left corner, where the leadership will come exclusively, if not primarily, from industry itself, and economic competitiveness (making money) is very much the issue. This is the way they see themselves. They do not see themselves in the center of that viewgraph. That's the point I want to make here. NSF is now emerging into engineering prominence. They see themselves perhaps at a more basic level where industry is expanded to include academia. But they see themselves very applied, nevertheless, and very much in line with the President's notion of economic competitiveness. NASA and DOE are both mission agencies. Of course, they have to work with industry because the benefit of those missions, since it's not in the constitution, is a little more broad and difficult to define.

The TRP program is that which we hope will connect all of those together. It has the breadth that it can span those two areas and moves into spin-on technologies up at the top right and spin-off technologies in the lower left. That's a pretty tall order and I guess I would, had I been drawing this chart, have made the bubbles bigger so that the TRP bubble could be smaller. Nevertheless, this is the way NIST and the rest of the TRP see our mission in the new scheme of things. I think there is a message there, and that message is: We're doing things in new ways, we have new tools, we're going towards new goals and we're interested in doing things that make sense and involve industry and defense as equal partners against an equally threatening mission. With that, I appreciate your attention and I would welcome you to join us for lunch.

Where We Are

- o WE WON! (The Cold War of Attrition)
- o NOW WHAT?

THE ROCK.....

- Threats and Missions Have Changed
- Force is Inappropriate to New Threat

THE HARD PLACE.....

- Budgets are Coming Down
- Little Resolve to Reconstitute

Two Problems

- Two Distinct Industrial Bases

Defense	Commercial
Threat Driven	Opportunity Driven
Bound by FAR	Responds to Market
Stockpile	Just-In-Time

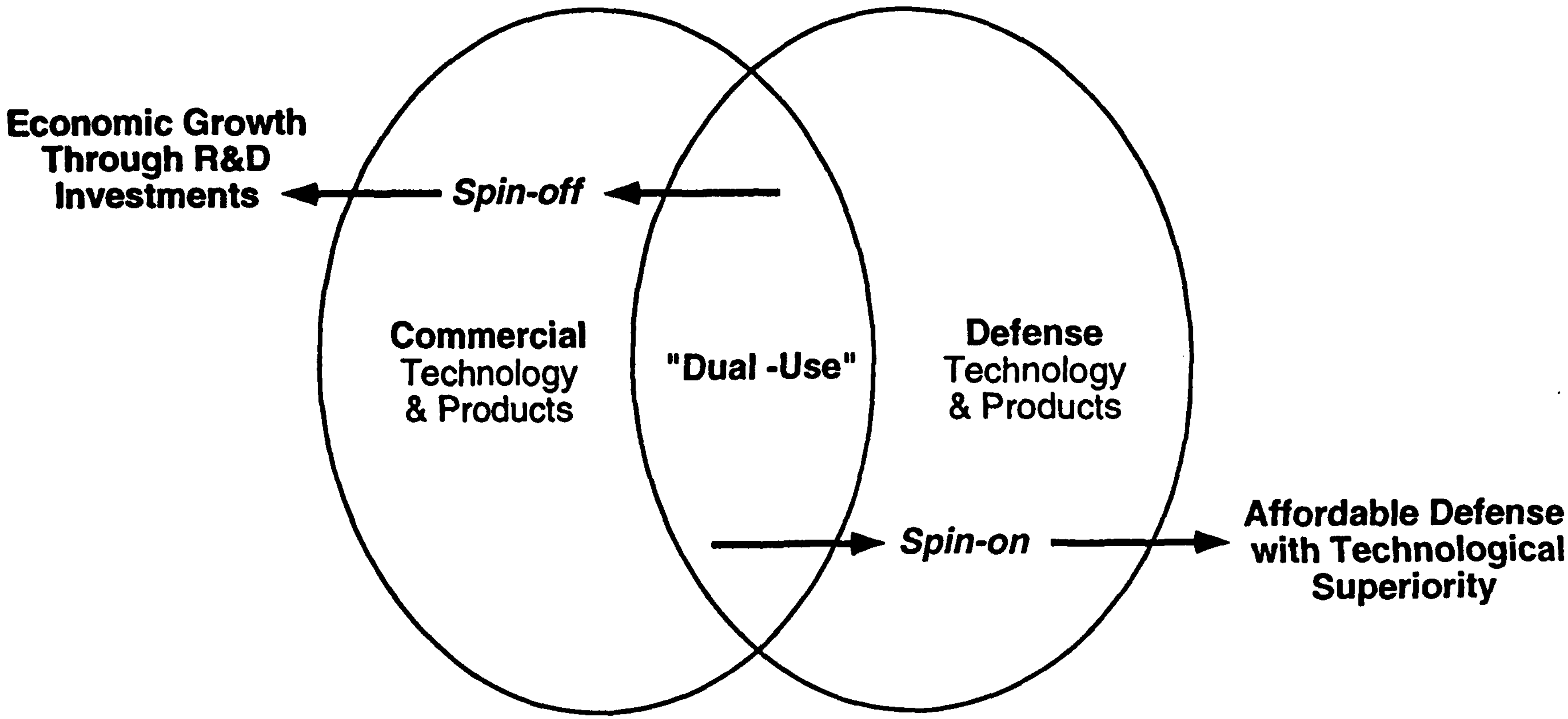
- Both Sluggish in Deploying New Technology

WE CAN'T AFFORD EITHER

What To Do?

- **Procurement Reform**
  - *Specifications, Cost Accounting, Oversight, etc.*
- **Develop Low Cost Manufacturing Technology**
  - *Flexible, Agile, Lean (Mantech)*
- **New Ways of Doing Business**
  - *Consortia, Partnerships, etc.*
- **Recognize/Exploit Commercial Markets**
  - *"Dual-Use"*

A Leveraged Opportunity



Dual-Use technologies have clear defense relevance and potential commercial viability

- o Vast Majority of ARPA Program are "Dual-Use"
- o Military Need Drives Military Investment
- o "Dual-Use" Can Drive Affordability
- o "Component" Technologies Seem Easiest
- o Commercial and Defense as Partners
  - Each motivated by self-interest
  - Each at risk

Goal: Leverage Commercial Markets

Examples

- Flat Panel Displays
- Electronic Components/Subsystems
- Composite Materials
- Computers and Networks
- Commercial Satellites

Systemic Obstacles

Impediment		Approach
No Market Demand	→	Identify technologies relevant to Defense with Commercial Potential
Unattractive Contracting Practices	→	"Other Transaction" Authority
Lack of Capital	→	Cost sharing based on: - relative military/civil payoffs & risks - ability of participant to contribute

Sociological Obstacles

Impediment		Approach
Not-Invented-Here	→	Exclusive rights to Intellectual Property
Technology Learning Curve	→	Numerical Simulation Insertion Programs
"Tech Transfer" Not Effective	→	Support sources capable of productizing Broker relationships
Perceived Risk	→	Prototypes and Pilot plants

Complimentary Approaches

	Traditional	Dual-Use
Defense Potential	Exclusive	Important
Management	Contract	"Partnership"
Risk Tolerance	High	Med/Low
Funding	DoD Sponsor	Cost Shared
Product Plan	Important	Crucial

Technology Reinvestment Project

Mission

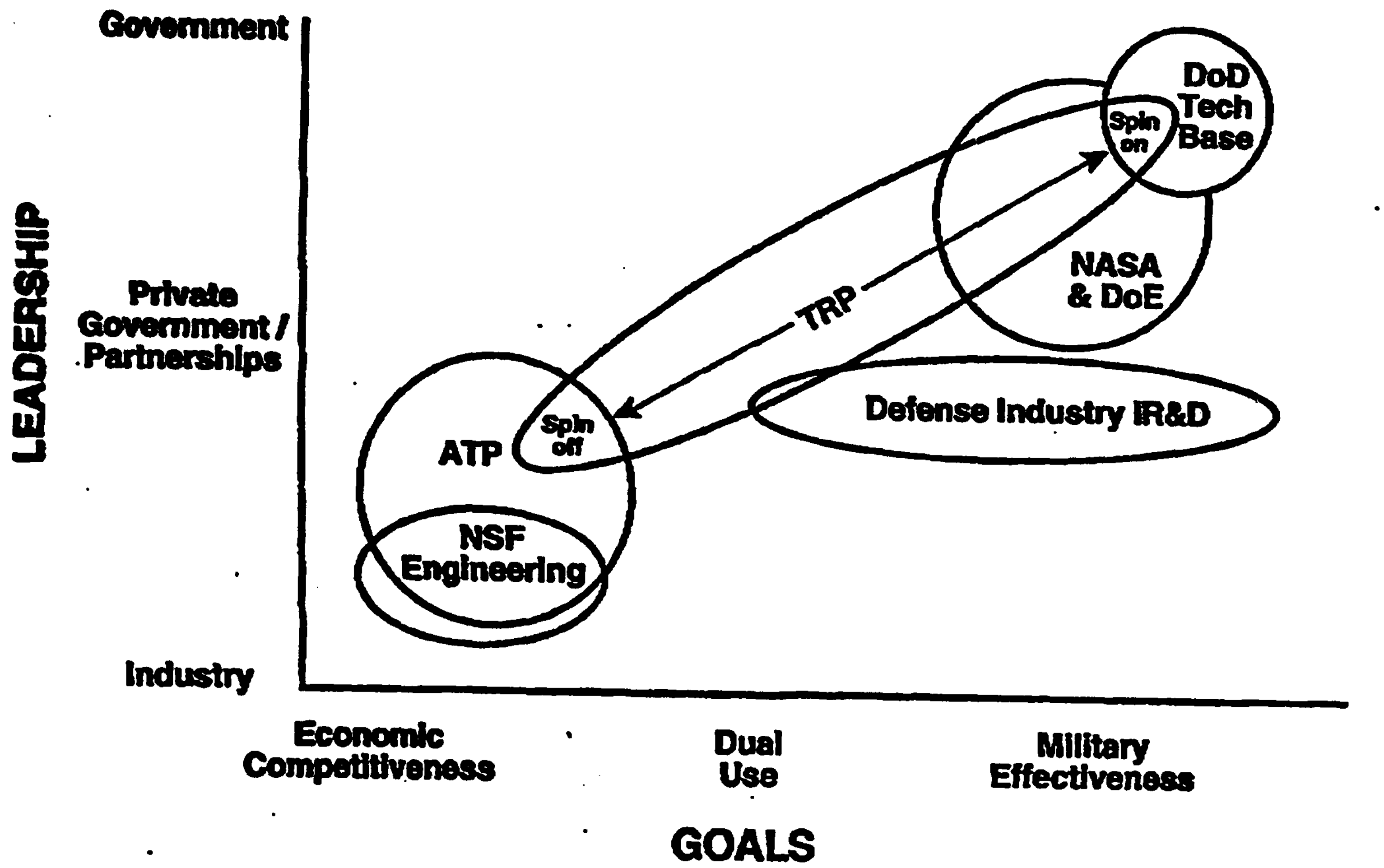
To stimulate the transition to a growing, integrated, national industrial capability which provides the most advanced, affordable military systems and the most competitive commercial products.

Strategy

Invest Defense Conversion, Title IV funds in activities which stimulate the

1) **<u>Development</u> of technologies which enable new products and processes**
2) **<u>Deployment</u> of existing technology into commercial and military products and processes**
3) **<u>Integration</u> of military and commercial research and production activities**

FEDERALLY SUPPORTED APPLIED RESEARCH



ARPA Vision Session

Chair: Dr. H. Lee Buchanan

II

II-A AFFORDABILITY

DR. MICHAEL F. MCGRATH

Affordability

Dr. Michael F. McGrath
ARPA-SSTO

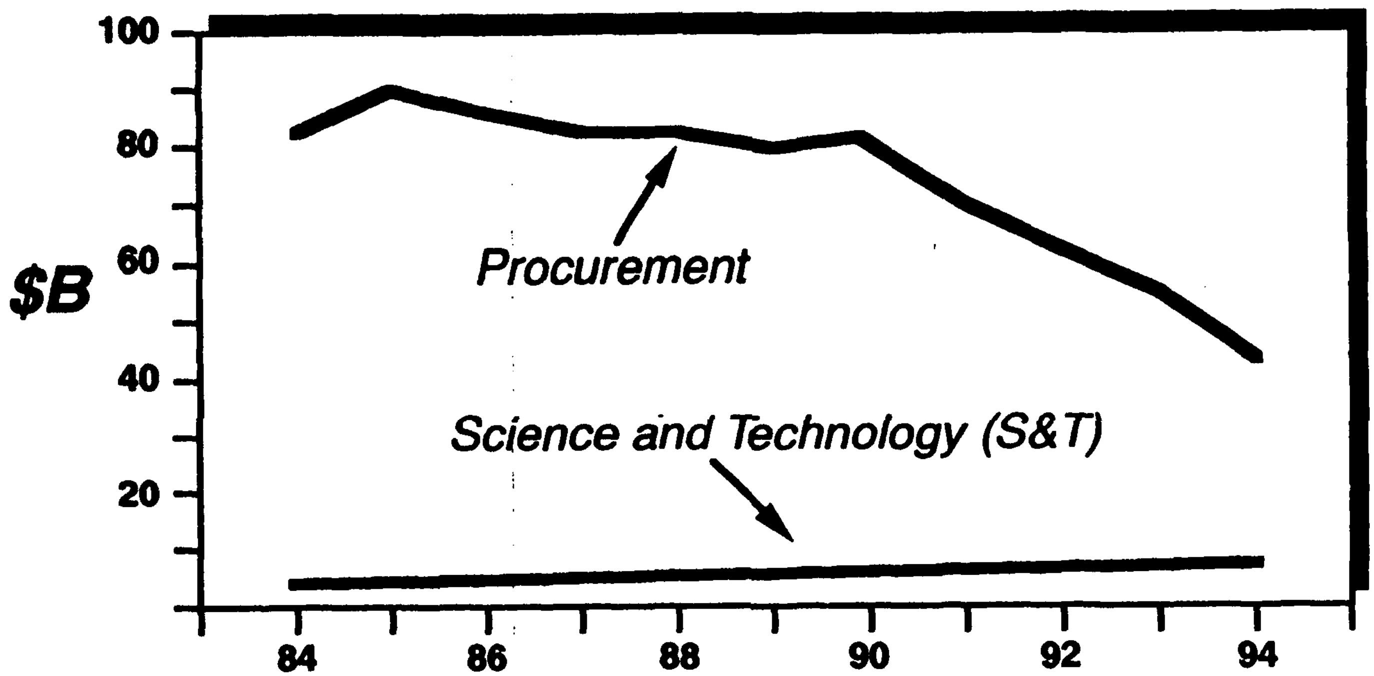
Outline

- Motivation
- DoD Technology for Affordability Thrust
- ARPA's Role
- Examples
- Implications for Industry

Affordability - More Important Than Ever

Changes in threats to the United States since the fall of the Soviet Union have reduced military materiel requirements. DoD plans to maintain its technological edge in defense systems by taking advantage of rapidly advancing commercial manufacturing process and product capabilities. As a key part of its strategy, DoD plans to invest in technologies that will make future defense systems affordable and that will make the US industrial base globally competitive and responsive to military needs. The commitment to this strategy is supported by the constant rate of outlays for Science and Technology (S&T) during a period when procurement outlays have fallen substantially.

Affordability - More Important Than Ever



DoD Strategy

- **Invest In Technology to:**
  - Make future defense systems affordable
  - Maintain a responsive industrial base

Technology for Affordability Needs

In this context of declining outlays for defense systems procurement, DoD's objectives are to build capabilities for affordable defense systems and for a responsive industrial base. The product realization process must be improved so that engineering designs can be developed rapidly and fully meet customer needs, and so that manufacturing processes can be designed to work economically with high-yield at low volumes of production. Advanced design of manufacturing processes will support multi-use production lines that can reduce overhead costs associated with product manufacturing.

The strategy to achieve these capabilities is two-pronged. First, there must be a technologically supported cultural change towards integrated product and process development (IPPD). It is the responsibility of each technology demonstration to help change the acquisition process to incorporate IPPD. Second, all technology development areas must focus specifically on enabling technologies, tools, and infrastructure. Emphasis must be placed on integrated engineering tools, models, and simulations; advanced manufacturing processes and materials; and flexible manufacturing systems.

Technology For Affordability Needs

Meeting These Future Military Needs

- **Affordable Defense Systems**
- **Responsive Industrial Base**
  - Rapid product realization
  - Economic low-volume production
  - Multi-use production lines
  - Reduced overhead costs

Will Require These Advances in Science and Technology

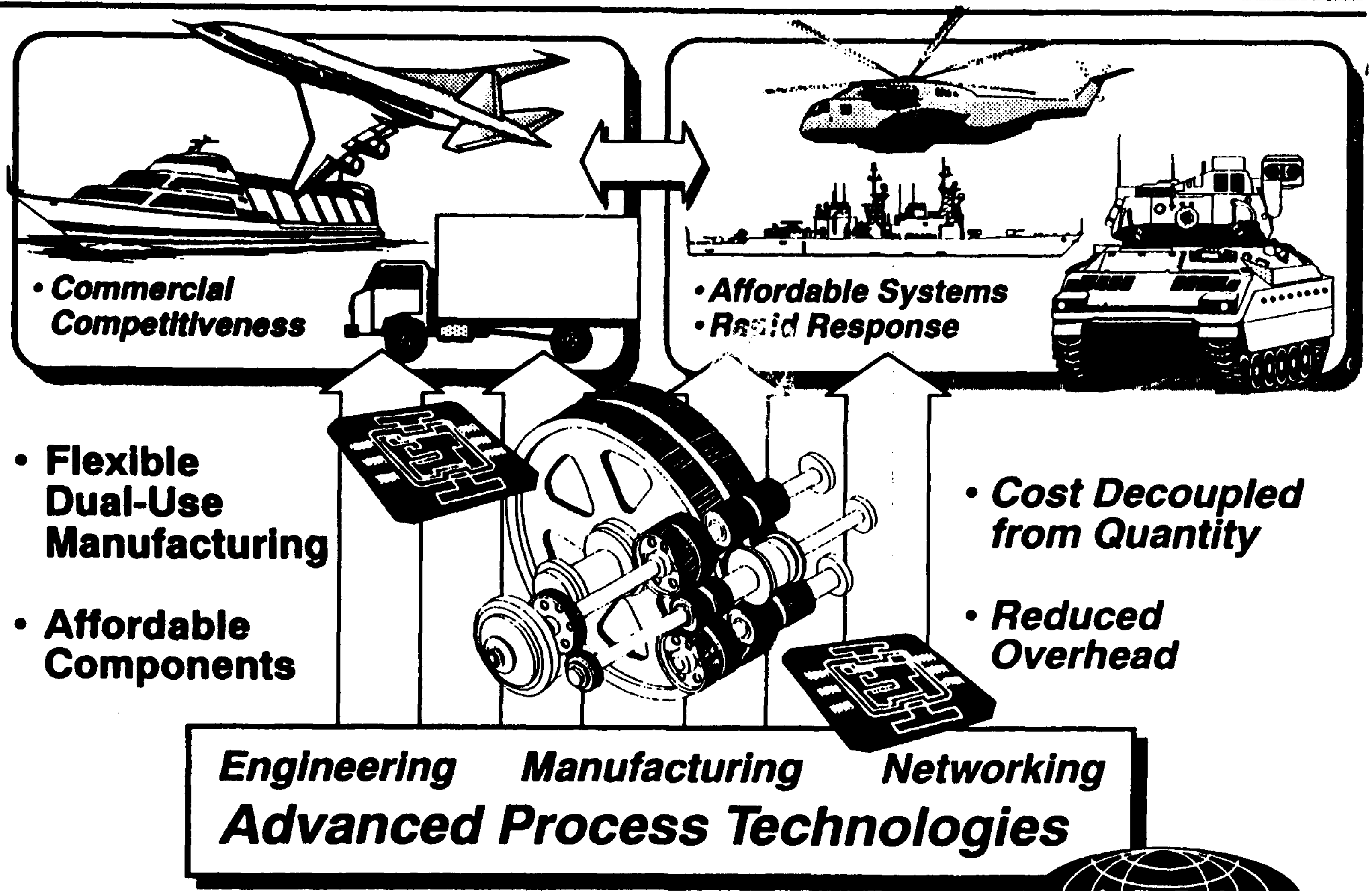
- **Integrated Product/Process Development**
- **Enabling Technologies, Tools, and Infrastructure**
  - Integrated engineering tools, models and simulations
  - Advanced manufacturing processes and materials
  - Flexible manufacturing systems
  - Enterprise-wide C^3 systems

Thrust 7: Technology for Affordability

Technology for Affordability

Many systems and platforms required by DoD have analogs in the commercial world. For example, ships, aircraft and land vehicles are needed by civilians as well as by the military. While there are major differences in the performance requirements of the top level platforms, when these platforms are decomposed into subsystems, common components may be identified. Where common components exist, opportunities for dual acquisition exist. Where specialized components are required, advanced engineering, manufacturing and communication technologies enable opportunities for dual-use design and manufacturing capabilities.

S&T Thrust 7
Technology For Affordability



- Flexible Dual-Use Manufacturing
- Affordable Components

- Cost Decoupled from Quantity
- Reduced Overhead

ARPA AFF 004-93

Where are we headed?

This comparison of typical current practice with future requirements shows that fundamental systemic changes will be implemented, and that these changes depend on integration of new, emerging and existing technologies.

The vision is of responsive, highly integrated design that feeds flexible, highly capable, low-overhead manufacturing — all woven together by the fabric of a national information infrastructure. Through organizational change, motivated by competition and economics, and enabled by technology, we will eliminate the over-the-wall, test-and-fix, capital-intense approach we depend on today.

Where Are We Headed?

Capability	Today	Future
Engineering	• Sequential Design • Minimum Focus on Producibility, Supportability • Incompatible Design Tools	• Integrated Product/Process Design (IPPD) • Multi-function Design Teams • Interoperable Tools, Models, Simulations
Manufacturing	• *"Mass Production" Paradigm* • Dedicated DoD Lines	• *Lean, Agile Manufacturing* • Flexible Systems to Decouple Cost from Quantity • DoD Access to Commercial Lines
Networking	• High Factory Overhead • Slow, Paper-based Processes	• Intra-company Integration to Attack Overhead • Inter-company Electronic Exchange of Engineering Data • Electronic Commerce

ARPA's Role in Technology for Affordability

DoD's Technology for Affordability program encompasses all manufacturing technologies that bear on creation of affordable defense systems. ARPA is responsible for the investment of approximately 70% percent of DoD outlays in technology for affordability. ARPA programs cover advances in design and manufacturing technologies and advances in integration of technologies required for improved product realization.

Major programs now underway in Electronics Manufacturing Technology include:

- Sematech,
- High Definition Systems,
- Multi-chip Modules Packaging, and
- RASSP.

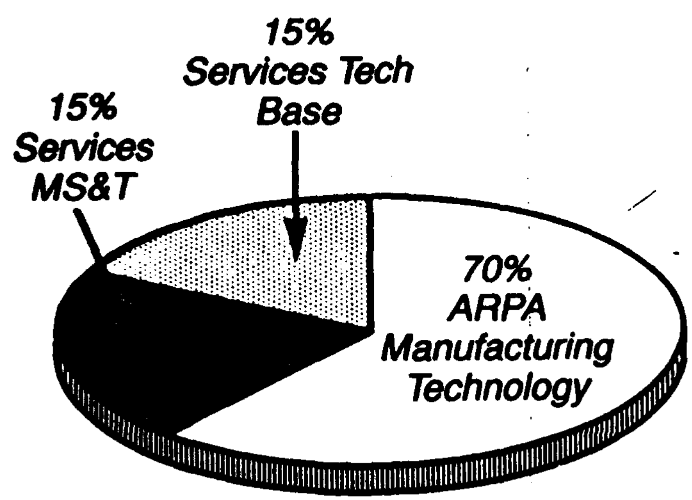
Programs on Materials Processing technology include a new focus on affordable fabrication processes, for example, for products using advanced composite materials.

Thrust 7 Advanced Technology Demonstrations are application-focused programs that will develop technologies for tool, process, and information integration for product realization. Examples of these ATDs come later in this briefing.

Systems level affordability programs include ARPA ASTO programs for Affordable Aircraft and the ASTOVL program.

ARPA programs on Enabling Technology and Infrastructure seek to create advanced design and manufacturing work environments. These environments will contain operational frameworks, integrated automated tools and applications to support product engineering and manufacturing process design, services to enable manufacturers to find suppliers quickly via an electronic market place, and information networks to co-locate electronically participants involved in product development enterprises.

ARPA's Role In Technology For Affordability



$1.1 B (FY-94)

DoD Technology for Affordability

- **Scope is "Big M" manufacturing**
- **ARPA responsible for 70% of DoD investment**

Major Programs

- **Electronics Manufacturing Technology**
- **Materials Processing Technology**
- **Thrust 7 Advanced Technology Demonstrations**
- **Systems Level Affordability Programs**
- **Enabling Technology and Infrastructure**

ARPA Manufacturing Technology Programs

These six themes underlie the ARPA approach to manufacturing and design technology. ARPA's programs tend to be based on specific system technologies, such as those required for missile seekers. The programs yield measurable results, and contain programmatic *mechanisms to harvest*, generalize and feed back broadly applicable results. Integrated product/process development is the foundation of ARPA's approach to product realization from requirements *capture and concept exploration through* development, production and delivery to the field, and, increasingly, retirement and disposal. The concurrent engineering aspects of IPPD feed multi-use manufacturing controlled by intelligent devices that assist in achieving first-pass success and eliminating test-and-fix design cycles. The use of information technology as leverage to achieve integration and flexibility is a natural theme for ARPA, and one which is showing success. ARPA's *strategy is to ensure technology transition to industry* by employing information technology vendors committed to commercialization. Finally, APRA focuses its efforts to achieve critical mass.

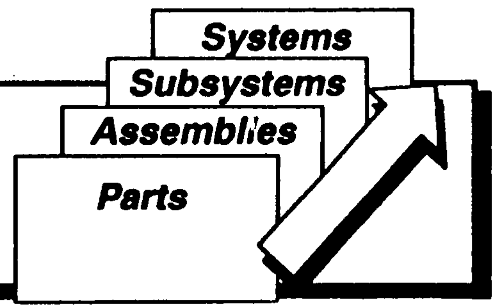
All these themes are evident in the ARPA electronics component technology programs of the recent past. These successes now provide a basis for addressing larger entities, such as assemblies, and eventually whole systems.

ARPA Manufacturing Technology Programs

Themes

- **Application Focus and Metrics**
- **IPPD, With Extensive Modeling And Simulation**
- **Flexible, Multi-Use Manufacturing**
  - Intelligent Process Control For First Pass Success
- **Information Technology (Tools, Knowledge Bases, Networks)**
- **Rapid Transition Through Committed Suppliers**
- **Critical Mass To Make A Difference**

Successes in electronic components have paved the way for higher level systems

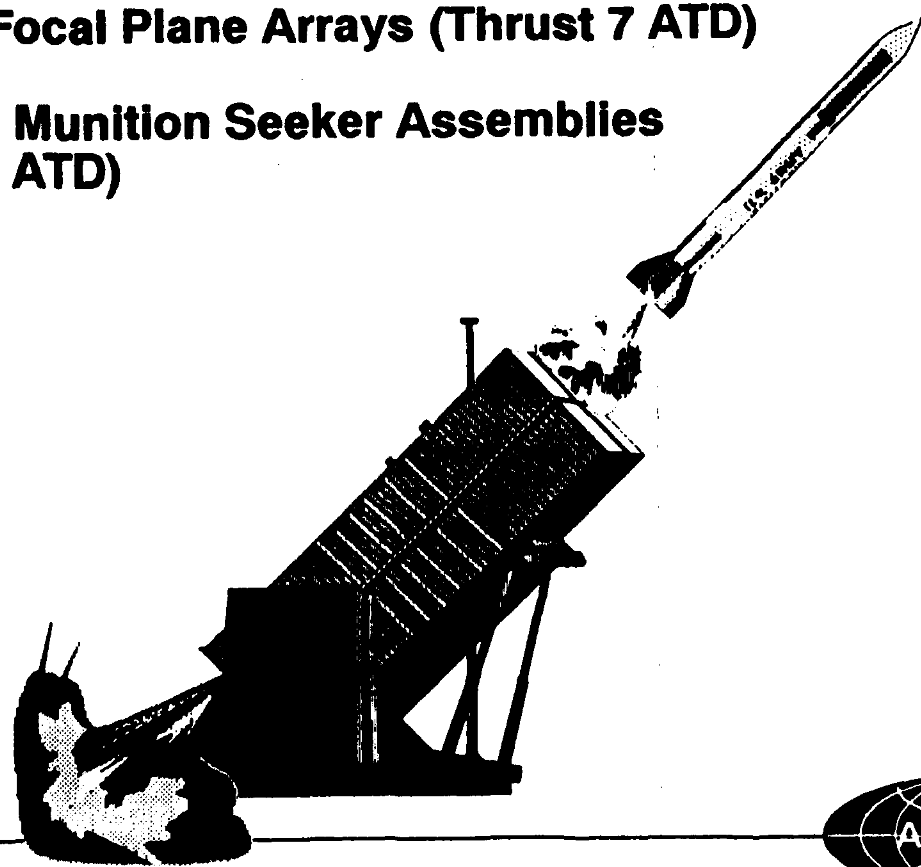


Examples

These are three example levels of missile integration that will be used to illustrate the path ARPA is following.

Examples

- Radar Transmit/Receive Modules
- Infrared Focal Plane Arrays (Thrust 7 ATD)
- Missile & Munition Seeker Assemblies (Thrust 7 ATD)

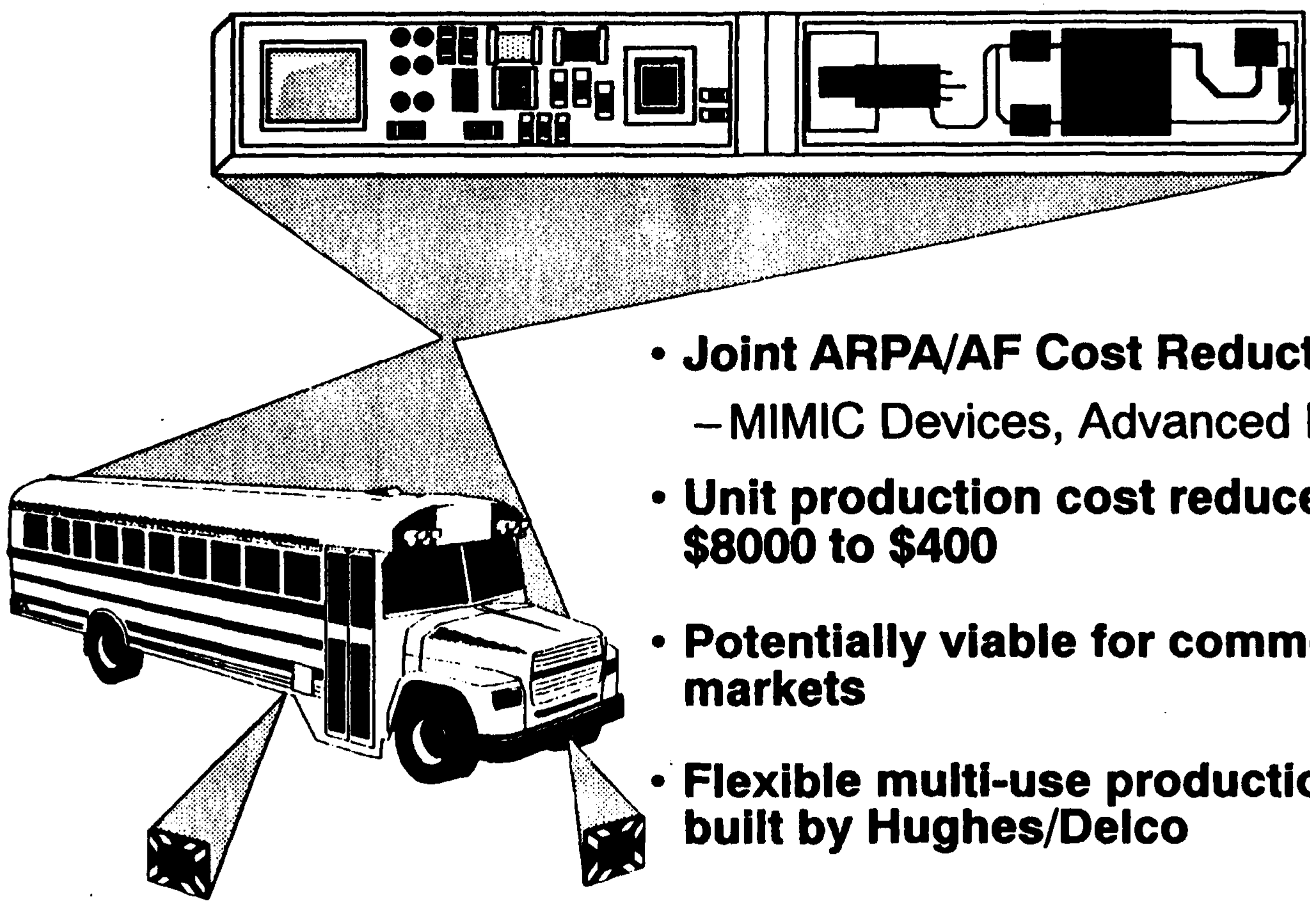


ARPA AFF 008-93

Radar Transmit/Receive Modules

ARPA and the USAF worked together to bring the unit costs of transmit/receive modules down to a level of potential commercial viability. Now we are trying to open a large new market so that DoD and commercial applications can draw from a common supplier. The example shown is of an affordable perimeter object detection system for school buses.

Radar Transmit/Receive Modules



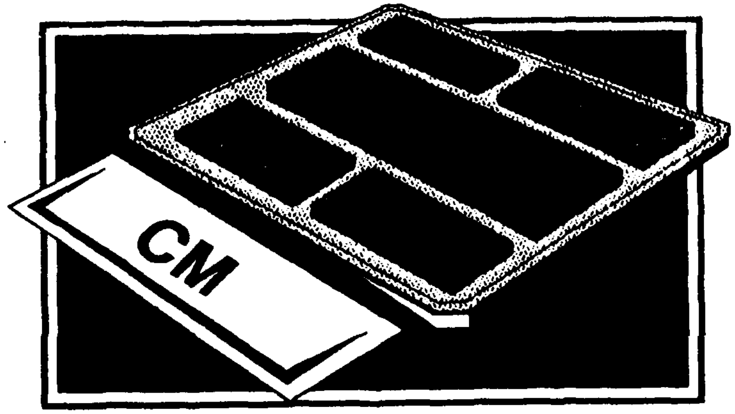
- **Joint ARPA/AF Cost Reduction Effort**
  - MIMIC Devices, Advanced Package
- **Unit production cost reduced from $8000 to $400**
- **Potentially viable for commercial markets**
- **Flexible multi-use production line built by Hughes/Delco**

IR Focal Plane Arrays

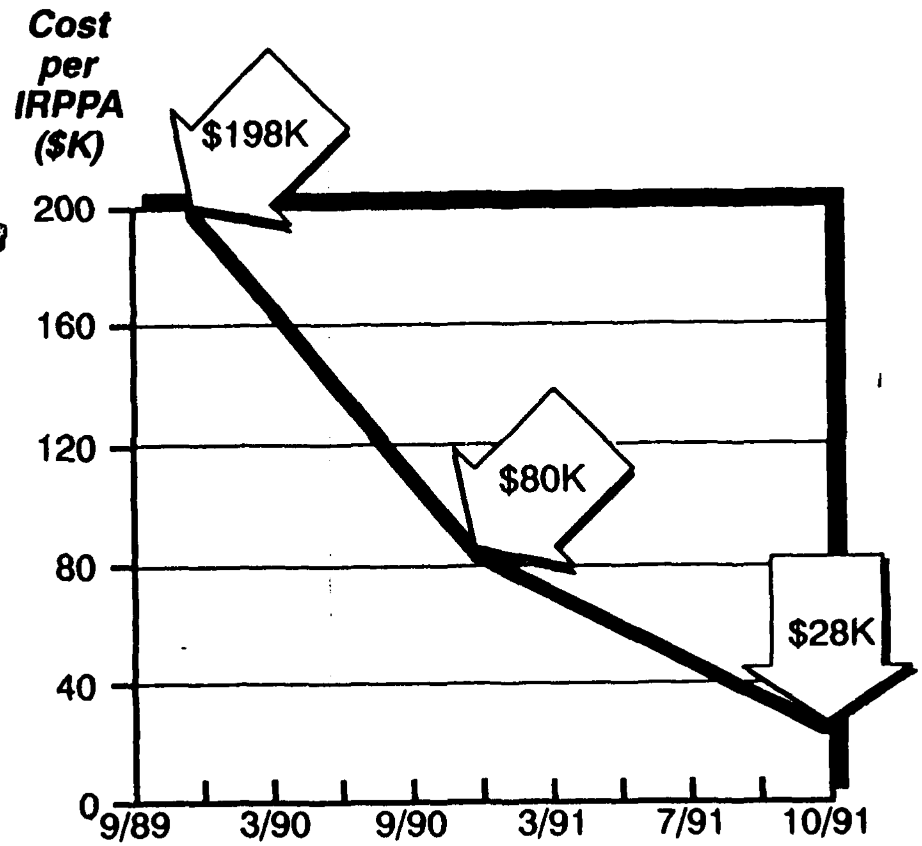
The costs of infra-red focal plane arrays have been driven down dramatically in the last few years, but further cost reductions are required. Prior efforts reduced unit cost through careful, continuous tuning of process parameters of the manufacturing process. Two major problems have been encountered in manufacture of IRFPAs. First is the history of starting over again each time a new IRFPA design is required. Second is the significant cost of capital that must be amortized over the low production volume associated with IRFPAs.

To break the non-recurring engineering problem, we must develop IPPD environments with useful design libraries and improved CAD/CAE tools to make use of them. To break the cost-quantity problem, new flexible manufacturing process are required that will achieve first pass success and that will meet the need for low cost production facilities.

IR Focal Plane Arrays



960 x 4 IRFPA
For Airborne
IR Target Acquisition



ARPA AFF 010-93

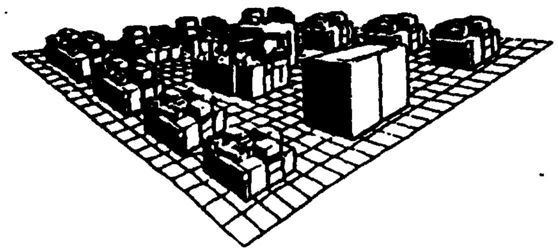
Thrust 7 ATD: IRFPA Wafer Fabrication Concepts

At the IRFPA wafer level, APRA's Thrust 7 ATD borrowed from a successful ARPA program on affordable, modular silicon wafer fabrication. Here we apply the same approach to HgCdTe materials resulting in robust, cost-effective, flexible processing. This approach decreases the up-front capital investment by decreasing the requirement for clean rooms: the environment is sealed within the equipment instead.

IRFPA Wafer Fabrication Concepts

Application of Modular Fabrication Facility to IRFPAs

Modular Wafer Fabrication Facility Concept from the Silicon IC Industry



- Designed for moderate volume rapid cycle time, multi-technology wafer processing
- Incremental capacity addition
- Clean room in the equipment
- Common modular equipmentfor flexibility and low cost
- Multiple processes brought to wafer
- Full computer integrated to run multiple designs and configurations
- Process control via in-situ sensing, feedback and feed forward
- Artificial intelligence and expert system computing

Electro-mechanical Assemblies

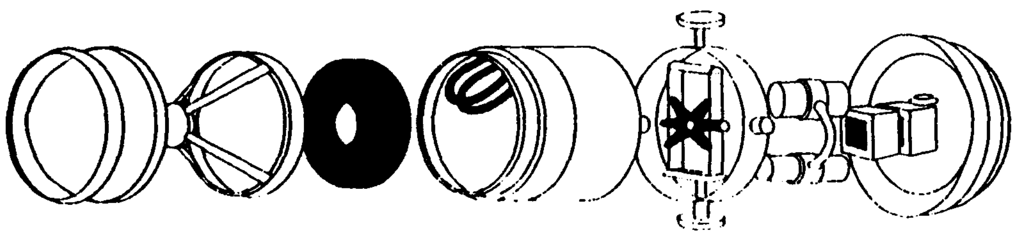
The Thrust 7 ATD for Flexible Design and Assembly of Missile and Munition Seekers (FDAMMS) focuses attention on manufacture of electro-mechanical assemblies. At the level of assemblies, multi-level mechanical engineering and systems integration issues emerge as drivers. The results of the design and manufacture of many disparate 3-D parts must be brought together under the control of flexible assembly processes to achieve optimized part integration meeting required tolerances in order to create high-quality assemblies.

To address these issues, development of advanced applications for mechanical design and for specification and analysis of assembly processes must be created. In this effort, the major focus will be placed on design for assembly. Infrastructures will be developed to support networked IPPD teams both within and across companies and to support development of flexible, multi-product assembly systems.

During FDAMMS, a series of demonstrations will be conducted that show integration into the Seeker design and manufacturing infrastructure of tools and components produced in other Thrust 7 ATDs. The tools and processes created during the demonstration will be available to industry for commercial development thus ensuring future availability and support for end users.

Electro-Mechanical Assemblies

Thrust 7 ATD - FDAMMS



Flexible Design and Assembly of Missile and Munition Seekers

- **Tackle issues at higher levels of assembly**
  - Mechanical engineering and system integration
  - Assembly process flexibility and quality
- **Develop advanced mechanical design and assembly capabilities**
  - Major focus on design for assembly
  - Networked IPPD for assemblies and components
  - Flexible, multi-product assembly capabilities
- **Progressive demos in seeker applications**
  - Customer for tools and components from other Thrust 7 ATD's
- **Significant commercial potential for tools and processes**

Implications for Industry

The Technology for Affordability initiative seeks to equip American industry with new methods and tools that should permit it to compete more successfully in commercial markets while supporting defense requirements. Commitment to integrated product/process design (IPPD) methods, with its emphasis on multi-functional design teams, gives companies and enterprises the means of addressing product requirements and issues affecting quality early in product development, and the means of avoiding costly redesign and rework. IPPD emphasis on the design of manufacturing processes concurrent with the design of the product allows companies to address issues of assembly that determine product manufacturability at cost and on schedule.

The rapid development of simulation capabilities give designers and customers powerful new tools to verify that requirements given are in fact the requirements needed, and to test the adequacy of product design. Simulation environments support designer interaction with manufacturing and testing of the product before it is created. This interaction allows design iterations to be conducted that lead to more sophisticated and capable product designs. This will be based on accurate 3-D representations of assembly and unit processes with reasonably seamless connection to operational simulation, such as the synthetic battlefield or automotive simulators.

The integrated design of manufacturing processes for products in IPPD, coupled with the capture of this process knowledge and the availability of programmable manufacturing tools, enable flexible or multi-use manufacturing. Automated support for manufacturing control permits leveraging of commonality among product lines and smooth transitions among product mixes.

The ATD's give industry application-driven environments for the creation and improvement of new tools for manufacturing and for tool integration in the engineering and manufacturing infrastructure. Improvements in technology will increase the set of applications and services that available to industry.

The use of IPPD methods, of new simulation technologies, and technologies exercised in ATD environments will provide significant cost, schedule, and quality improvements in the deployment of new products, both civilian and military.

Implications For Industry

- IPPD as a way of life in technology programs
- Balanced emphasis on process as well as product performance issues in S&T
- Simulation based design
- Multi-use manufacturing
- Replication of accomplishments of ATD's
- Bottom line improvements in cost, leadtimes and quality

II-B INNOVATIVE TECHNOLOGIES

DR. LANCE A GLASSER

✓✓

Innovative Technologies
Arpa Symposium

1. **Innovative ARPA Technologies**

Welcome, today I would like to tell you about some innovative technologies that ARPA has developed and is looking forward to developing over the next 5 to 10 years.

2. **ARPA Megatrends**

The last 5 years has seen many changes at ARPA starting with the change from DARPA to ARPA. We have become an agency where we are concerned not just about the traditional DoD need to have higher performance but to have that performance affordable. We have changed from being DoD driven to dual use driven We have changed from being simply cognizant of the market to being much closer to the commercial markets. We have, over the last 5 years, seen a large increase to internal cooperation with larger programs that span many offices, such as the electronic packaging program and high performance computing. In the future we are looking forward to more inter-agency cooperation where we have cooperation between ARPA and DOE, ARPA and NIST, etc.. We have seen a change from simply the use of contracts for goods and services under the Federal Acquisition Regulations to the start of a new R&D acquisition process that uses the ARPA authorities for "agreements" and "other transactions".

3. **The ARPA mission**

The ARPA mission is to change people's minds as to what is possible. It used to be that ARPA change people's minds by simply producing a new product that nobody had ever seen before, like an airplane that nobody could see. Today, however, if we were to develop the first stealthy aircraft, people would ask embarrassing questions like can we afford it? can we maintain it? can we manufacture it? So today, in order to change people's minds as to what is

93-S-2175

possible, we have to not only produce one of the products, but show that it is manufacturable and affordable.

4. ARPA Core Technology Base Competencies

The ARPA core competencies are information technology, electronics, and materials. I will, in the next part of the presentation, go over where ARPA is going in each of these major core competencies. We'll start with information technologies. The new thrust in information technology is national information infrastructure (NII) which Duane Adams talked about earlier today. Issues in network architecture have to do with scaling the number of users the number of nodes by over 100-fold, riding the wave of analog to digital conversion in TV and police and emergency civilian radio and new economies of scale for digital transmission by the radio waves the first and last mile. We will, of course, continue to transmit voice and electronic mail data, but there will be increasing emphasis on maps, images, and video. And in order to cope with all the information on the national information infrastructure, we'll need intelligent systems for finding information, for finding people and for finding things on the NII. We'll also be applying the NII to education and training.

5. Information Technology Growth Areas at ARPA

There will be many new information technology functions needed in the future. Human computer interactions will be increasingly important to match the resources of the NII and high performance computing to human beings. This means speech, writing, gestures, pictures and even tactile displays; and the software that brings all these things together in multi-modal computer interaction with human beings. There will be an increased emphasis on associate systems. In the past, ARPA did a few programs to develop associates such as Pilot Associate. We will see increasing demand for such associate systems to try to generalize on some of the knowledge we've developed in the past. Intelligence system environments will help people work on problems such as image or understanding speech or planning. There will be increased emphasis on

distributed collaborative problem solving. Getting teams of people from around the world focused on a common problem and of course the perennial problem of software. We're moving to a model of software that says software isn't designed once and for all but is a continuing evolving system. We want to rapidly and continually evolve software systems and that means additional work on methodologies and tools for heterogeneous software systems composed of many different subsystems with intelligent documentation. Documentation has always been a problem in software. We'd like to automatically generate documentation. Domain specific software architectures have seen some work at ARPA already and are supporting domain specific software architectures, reuse, digital libraries, domain specific software architectures, and many other technologies for moving from a model of software programming to a model of software construction. Information technology problems in the future have to deal with the vast quantities of information that will be available. This information will be distributed, it will be heterogeneous, it will be multi-modal, it will be old software, there will be new software, and we will be looking at information brought in from many many different sensors.

6. Electronics Technology Growth Areas at ARPA

Electronics has grown over the last decade from investment of a few tens of millions to an investment of a few hundreds of millions of dollars. We expect to see an increased emphasis on electronic packaging and interconnect. Today that program is focused on the multichip module level. Tomorrow we it expect to be focused on higher levels of assembly. We also expect our high speed digital program and microwave millimeter wave program to begin to merge. Also, optics begin to merge with this so that we have digital, we have analog, we have optical, we have microwave to millimeter wave, we have microelectromechanical systems and we have mixtures of all of these. The electronic packaging and interconnect problem of the future will be driven by the performance and by form factor. Form factors are an increasingly important parameter. We're looking for affordable, scalable, and flexible, manufacturing of electronics. I will talk more about manufacturing a little later in the presentation. We're going to see an

increase in emphases on microelectromechanical systems. Microelectromechanical systems are the small microsensors and microactuators that allow microelectronic systems, not just to compute, but to sense and affect the environment around them. We expect to see a large increase in the microelectromechanical systems program at ARPA over the next few years. With the increasing thrust at ARPA in mobile electronics systems, electronics for low power will be receiving increased emphasis at ARPA, from the device level to batteries to system architectures.

7. Materials Technology Growth Areas at ARPA

There's an interest in exploring hardware architectures to relieve software bottlenecks; artificial neural networks are an example of hardware technology that tries to make a software problem easier by building a hardware architecture that supports learning. Flexible manufacturing of affordable infrared focal plane arrays and the rapid development of application specific signal processors are new thrusts in technology for affordability. In conjunction with ARPA's work on national information infrastructure we expect ARPA to again get heavily into wireless communication as an extension of our work on distributed mobile information systems. ARPA has had considerable work in the past on photonic interconnect; the new thrust will try to make that photonic interconnect more affordable, more accessible, more usable systems. Finally, we will continue to press on developing new device technologies--device technologies that emphasis room temperature operations because we understand that most mobile systems of course work at room temperature.

8. Manufacturing

In the materials technology area, we're looking at increased growth in application-driven materials programs. The idea will not simply be one of trying to make the best materials but trying to make those materials in ways that are tightly coupled to customer programs for those materials. We are looking to make those materials affordable both in terms of the materials themselves and the way those materials are formed into structures. We're looking for synergy between our materials program and electronics programs. Materials for electronics is an

important area and smart materials is an area materials program overlaps with the microelectromechanical system program. Rapid prototyping is a theme for materials as it is for electronics and information systems. More on that later. The materials program is closely coordinated with the FCCSET process (Federal Coordination Council for Science, Engineering and Technology), where ARPA is involved in the advanced materials and processing initiative.

9. ARPA's New Focus on Process is Synergistic With Our Focus on Dual Use

Manufacturing efforts at ARPA have grown from almost nothing a decade ago to over a third of the ARPA budget. The agency seeks to integrate the product and process at the R&D stage. This new focus on process is synergistic with our new focus on dual use because processes, especially at the systems level, are more dual use than products.

10. Manufacturing Growth Areas at ARPA

Over the next decade we expect the ARPA programs in manufacturing to push affordability, to push rapid manufacturing learning, flexible manufacturing, scalable manufacturing (in the sense that we want to build small factories that affordable and that can be scaled into large factories that are affordable). Synthesis and simulation is often used in electronics and is often used in software; we will be extending those concepts to more and more complicated processes in manufacturing areas. In order to make processes very flexible, very changeable, there has to be tight feedback between what the manufacturing equipment is doing and what it is that one wants and what is simulated and synthesized. That's where sensor based manufacturing comes in. It will be an application area for the affordable microsensors and microactuators I talked about earlier. We'll be driving manufacturing from the processor oriented manufacturing we have today to assembly oriented manufacturing and manufacturing at higher levels of assembly, for instances mechanical assemblies or electromechanical assemblies. We will try to exploit synergy between manufacturing and national information infrastructure and between manufacturing and high performance

computing and try to deploy those resources on the manufacturing problem. I've already mentioned microelectromechanical systems which those are exciting in that they are not just a new set of devices but a new way of making those devices. Last, but certainly not least, we're seeing a hugh increase in environmentally conscious design and manufacture.

11. Rapid Prototyping

The rapid prototyping theme is expanding with the recognition of the role that rapid prototyping plays in rapid learning. Prototyping technology is spreading from pioneering work done in the early 80s microsystems, such as the MOSIS system, to rapid prototyping of everything, including software languages for software prototyping, prototyping of signal processors, (the RASSP program), a multichip modules extension to in MOSIS semiconnector processes prototyping, electromechanical part prototyping, optoelectronic integrated circuit prototyping, and solid freeform manufacturing of a variety of sorts.

12. Conclusion

Let me end by speculating a little bit about the future in terms of core competencies. I mentioned information technology, electronics, and materials as ARPA's core competencies. Any organization has to think about what core competencies they are developing for the future and my speculation as to where ARPA might be going as far as new core competencies would be to try to develop a significant core competencies in medicine and biology.

Thank you very much.

ARPA Megatrends

Performance	➡	Performance and Affordability
DoD driven	➡	Dual-use driven
Cognizant of the market	➡	Close to the commercial market
Interoffice cooperation	➡	Interagency cooperation
Contracts, FAR	➡	New R&D acquisition process using Cooperative Agreements and Other Transactions

The ARPA Mission

The ARPA mission is to change people's minds as to what is possible

Today, this requires showing that a new idea is also manufacturable and affordable.

ARPA Core Technology
Base Competencies

- Information Technology
- Electronics
- Materials

Information Technology growth areas at ARPA (~~cont.~~)

- Human-computer interaction (via speech, writing, gestures, pictures, tactile, etc.)
- Associate systems
- Intelligent system environments (image understanding, speech, planning)
- Distributed collaborative problem solving
- Rapid and continuously evolving software systems--methodology and tools, heterogeneous software systems, intelligent documentation, Domain-specific architectures, agent-based programing, programming → software construction
- Mediator toolkits

vast quantities of (distributed, heterogeneous, multimodal, legacy, multisensor, . . .) information

Electronics Technology growth areas at ARPA

Increased emphasis on

- Electronic packaging and interconnect at higher levels of assembly (digital, analog, optical, microwave and mm-wave, MEMS, mixtures)
- Affordable scalable flexible manufacturing
- Microelectromechanical Systems (MEMS)
- Electronics for low-power systems
- New work in sensors, sources, actuators, energy sources, & displays

Materials Technology growth areas at ARPA

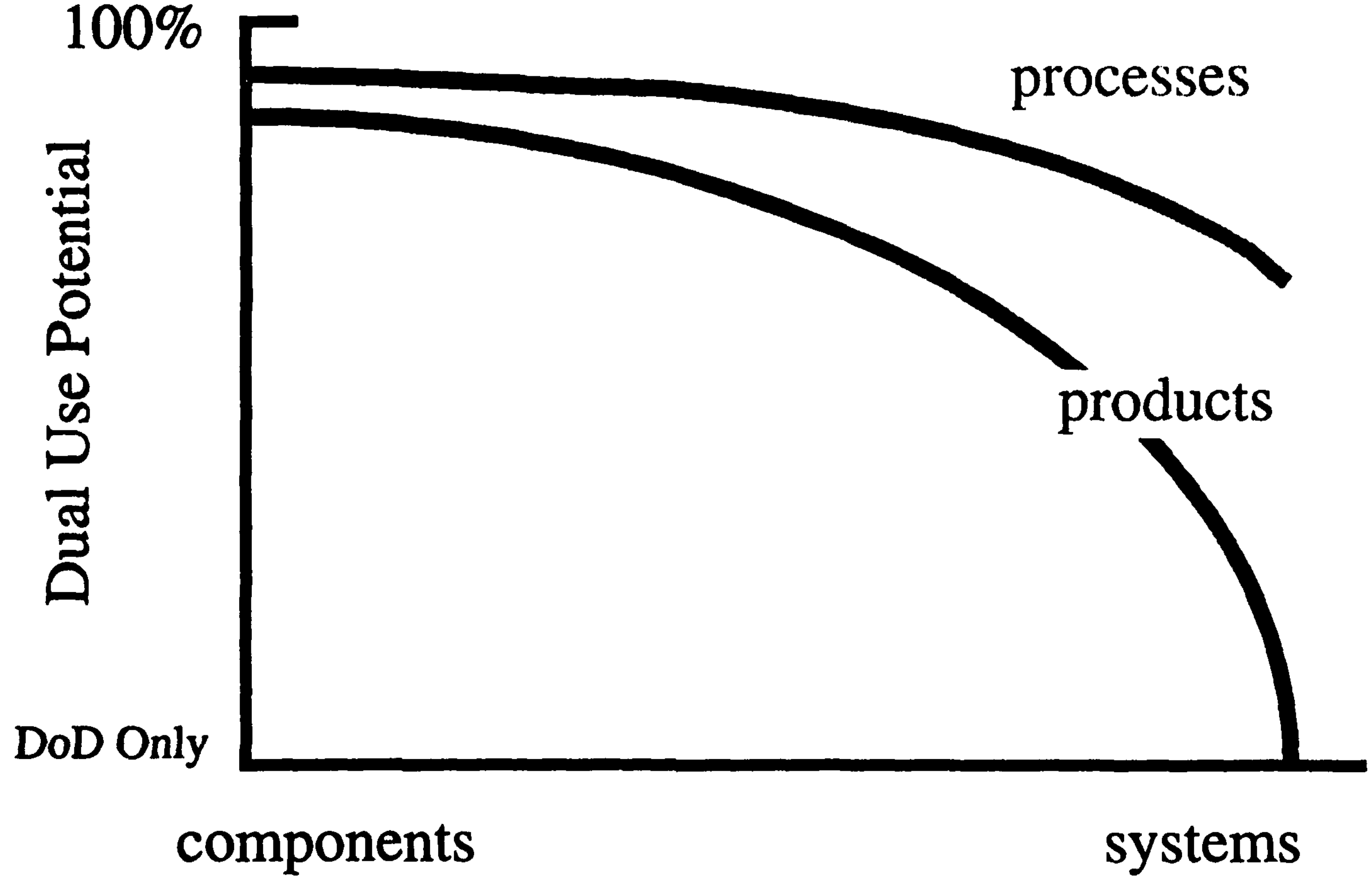
Increased emphasis on

- Application-driven materials programs
- Affordable materials and innovative forming technologies
- Materials for electronics
- Adaptive or "smart" materials
- Rapid prototyping
- Federal coordination of an initiative in Advanced Materials and Processing through the Federal Coordinating Council for Science, Engineering and Technology (FCCSET)

Manufacturing

Manufacturing efforts at ARPA have grown from almost nothing a decade ago to over a third of the ARPA budget as the agency seeks to integrate product and process at the R&D stage.

ARPA's new focus on Process is synergistic with our focus on Dual Use



Manufacturing growth areas at ARPA

Over the next decade we expect increased emphasis on:

- **Affordable manufacturing, rapid manufacturing learning, flexible and scalable manufacturing**
- **Process synthesis and simulation-based design**
- **Sensor-based manufacturing** (coupled to process synthesis)
- **Manufacturing of higher levels of assembly** (e.g., electromechanical assemblies)
- **Exploitation of the National Information Infrastructure and high performance computing**
- **Rapid prototyping of more complex subsystems, including software and mechanical assemblies**
- **Microelectromechanical Systems Manufacturing**
- **Environmentally conscious design and manufacturing**

Rapid Prototyping Theme Expanding

In recognition of the role of rapid prototyping in rapid learning, prototyping technology is spreading from the pioneering work on microsystems prototyping in the 1980s to the rapid prototyping of everything, including

- software, including languages for prototyping
- signal processors, e.g., the RASSP program
- electronic modules
- semiconductor processes
- electromechanical parts
- optoelectronic integrated circuits (OEICs)
- solid free-form manufacturing

ARPA Core Technology
Base Competencies

- Information Technology
- Electronics
- Materials

<new> Medicine and Biology??????!

II-C FUTURE MILITARY TECHNOLOGIES

MR. RONALD D. MURPHY

FUTURE MILITARY TECHNOLOGIES

June 22, 1993

Presented by:
Mr. Ronald D. Murphy
Director, ASTO
Advanced Research Projects Agency

0257-93

G 2 - Vision

The Cold War has ended and DoD is entering a new era which is complex and uncertain. Traditional mission structures are changing and our forces must learn to operate in new and creative ways with smaller forces and reduced infrastructure. These new forces must be affordable and developed within an industrial base that is rapidly downsizing its military business activities. This defines the challenge for force planners and technology developers in the new national security environment.

However, I believe that this new threat is more challenging in many ways than the old. Unrestrained by superpower intervention, regional powers with sizeable forces equipped with the latest technology have become increasingly active in promoting regional interests long submerged by the Cold War. New threats of all kinds are unpredictable and unconventional and have their own rationales and rules for employing conventional forces and weapons of mass destruction.

Future scenarios for military operations will mix regional conflicts with unconventional actions, some of which have already impacted planning for our forces. Urban warfare, illegal drug activity, terrorist actions and partisan conflicts ranging from small and localized to large and regional are increasing in number and intensity. Peacetime operations under conditions of restrictive rules of engagement and ill-defined relations among competing forces complicate aspects of our operational planning. Coalition operations in international task forces under *United Nations sanction* pose additional problems in planning, command, control and communications. Small conflicts may transition to much larger ones in ways and according to rules not found in the more orderly superpower confrontation. Especially challenging is the potential escalation to the use of weapons of mass destructions and the expectation of limited collateral damage and no civilian casualties.

While U.S. interests remain global and are increasingly concerned with humanitarian, political and economic factors, our military forces face declining resources. At the same time the public insists on achieving quick, decisive victories with ultra-low casualties and ultra-precise application to strike force across the entire spectrum of conflict. The ARPA vision is to develop innovative and affordable technologies and concepts that further the attainment of these goals for our future forces.

VISION

Humanitarian

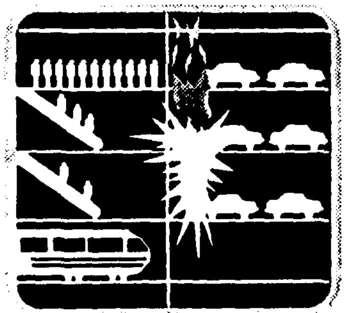
Crisis Management

Innovative Technologies to Enable Fielding of Affordable, Decisive Forces Capable of Quick, Low-Casualty Victories Across the Spectrum of Future Conflicts

Counter-Drug

WMD Proliferation

Terrorist Activity



Warfare

Peace Keeping

0258-93

VG 3 - Challenge

During the Cold War, U.S. and allied forces were continuously faced with the need to achieve credible capabilities against a numerically superior adversary. Initial reliance was placed on nuclear forces to compensate for inferior conventional forces but by the early 1970s the threat of first nuclear use had lost much of its credibility and conventional force multipliers became a vital requirement. ARPA met this challenge by providing the basic technology for such force multiplying systems as airborne surveillance with JSTARS, stealth aircraft, ATACMS, precision guided munitions, and low observables. These technologies are being fully integrated into our forces and were used with devastating effect against the Iraqis in DESERT STORM.

The environment of the 1990s is placing stresses on military planners and technology developers that are in some ways analogous to those experienced in the early 1970s. In the earlier era, the constraint was our inability to field forces numerically as strong as our adversaries. Today's constraints are somewhat different. There will be reduced resources for all aspects of defense. The services' force structure will be reduced along with the number of critical large-scale exercises. The infrastructure which once supported global deployments in substantial numbers will be reduced or eliminated with only forward presence forces remaining. Deployments of U.S. forces will increasingly be made to support international joint/coalition task forces, unlike the fully configured U.S. forces once expected to handle most situation overseas. The severity of these constraints forces new solutions to be developed for the future. The challenge is to turn this into an opportunity to forge a new revolution in warfare for the 21st century.

The exact shape of the new technologies needed for this revolution is not yet defined. However, certain themes can be identified.

- U.S. forces need superb situational awareness, real-time, and on a global basis as the logical continuation of the surveillance and reconnaissance initiatives of past technology base programs -- a force exponentiator instead of a force multiplier;
- Smaller forces will need superb readiness with high mobility for timely deployment of highly effective forces worldwide and sustainability in distant deployments to compensate for reduced numbers and infrastructure assets;
- Forces must be supported by a research and industrial base that provides generational dominance in advanced military technologies while enabling the acquisition of systems that are affordable in the required numbers.

In the main, this defines the challenge for technology development over the next decade.

CHALLENGE

CONSTRAINTS

- OPERATIONS WILL BE JOINT/COALITION
- FEWER EXERCISES
- REDUCED FORCE STRUCTURE
- FORWARD PRESENCE ONLY
- REDUCED RESOURCES

TECHNOLOGY THRUSTS

- SUPERB GLOBAL SITUATIONAL AWARENESS
- SUFFICIENT READINESS AND SUSTAINABILITY FOR TIMELY DEPLOYMENT AND EFFECTIVE EMPLOYMENT
- RESEARCH AND INDUSTRIAL BASE THAT SUSTAINS TECHNOLOGY EDGE AND PROVIDES AFFORDABLE SYSTEMS

0259-93

VG 4 - Investment Strategy

ARPA has historically developed advanced technologies and high performance systems that produced orders of magnitude improvements in performance with life cycle cost implications being of secondary consideration.

Three years ago, ARPA modified its investment strategy to include cost as well as performance. Integrated Product and Process Development (IPPD) was adapted as a means to address the affordability issues. IPPD offers the ability to address cost and performance trades among all constituent elements within a total warfighting context, thus supporting improved effectiveness and affordability. Concept evaluation and trades performed at these higher levels will contribute to an understanding of how performance affects warfighting capability and the marginal costs of those performance attributes.

In addition to focusing on implementation of IPPD, we are investing in not just the traditional high performance systems, but a much broader range of development activities including readiness and training, planning and deployment, and innovative operational concepts. Only by understanding and attacking the critical nodes and junctures across this spectrum of activities can we expect to achieve affordable and effective military capability.

INVESTMENT STRATEGY

- DEVELOP AND DEMONSTRATE ADVANCED TECHNOLOGIES AND SYSTEMS
- UTILIZE INTEGRATED PRODUCT AND PROCESS DEVELOPMENT (IPPD)

TRAINING AND READINESS

RAPID PLANNING AND DEPLOYMENT

INNOVATIVE SYSTEMS

OPERATIONAL CONCEPTS

AFFORDABLE-EFFECTIVE MILITARY CAPABILITY

VG 5 - Training and Readiness

Training and readiness are areas of vital interest to all elements of the Department of Defense. Our experience in mobilizing for Desert Storm taught us that not all units achieve full operational readiness with equal ease.

Our ambition for training and readiness is high: to provide the best possible combat training system at the garrison or armory, on the ship and in every other element of the joint environment. Toward that end, we are employing the powerful but cost effective approach of Advanced Distributed Simulation. We are constructing a seamless synthetic battlefield for widely dispersed units, weapons and all other force elements. The result is tremendous savings in the elimination of the usual major transportation requirement plus dramatic increases in the effectiveness of the actual time spent in training.

The Synthetic Theater of War program is aimed specifically at active forces including their commanders and staffs whereas the Army National Guard program will revolutionize the training process for reserve component units and individuals.

TRAINING AND READINESS

VISION

A HIGH-FIDELITY TACTICAL TRAINING ENVIRONMENT WHICH IS AFFORDABLE AND ENABLES THE HIGHEST DEGREE OF READINESS FOR BOTH ACTIVE DUTY AND RESERVE FORCES

- SYNTHETIC THEATER OF WAR
- NATIONAL GUARD TRAINING

0261-93

VG 6 - Synthetic Theater of War

Until recently, the concept of creating a high fidelity synthetic wartime environment that provides increased warfighting readiness and at the same time reduces cost and minimizes environmental impact has been an unattainable goal. Through application of state-of-the-art information technologies, this goal is on the verge of becoming a reality. The Synthetic Theater of War program is combining live, virtual and constructive simulation in a seamless environment where systems and people will meet to perform joint warfighting exercises and training will be much more consistent with the way we fight the war.

Our approach includes proving the concept of joint task force operations in 1994 by linking the Southwest USA training ranges with a joint task force headquarters and synthetic forces. The JTF and subordinate commanders may be located at their assigned home stations yet maintain full visibility of the combat operations being conducted in the synthetic environment battlespace. Their decisions and actions will occur as they do during active combat. Real weapon systems will be employed against virtual weapon systems and simulators of actual weapon systems.

The concept is to provide the challenge of a realistic, dynamic free-play environment not only for the conventional commanders and staffs that have been wargaming for years, but also for units, crews and individuals. Traditionally, results are based on how decisions and maneuvers are treated by the algorithms developed for the wargaming software. In the synthetic theater of war, many constraints imposed on live exercises are removed and the unexpected is introduced by the irrevocable maneuvers of real aircraft, tanks, etc., as well as the irrevocable maneuvers of manned simulators. Success means realistic combined arms warfighting can be experienced and evaluated, doctrine can be developed and evaluated, the high cost of deployment for training can be reduced as can the use of consumables and spare parts, and we can reduce the cost of repairing torn up countryside.

We will conduct Advanced Technology Demonstrations of this initiative as part of the Louisiana Maneuvers in 1994 and 1997. The Louisiana Maneuvers serve as virtual large scale field exercises that provide a test bed for refining technologies and strategies. Our Advanced Technology Demonstrations will employ technologies such as Distributed Interactive Simulation; Intelligent Gateways and Smart Switches; Modular Semi-Automated Forces (MODSAF) and Intelligent Automated Forces (IFOR); and advanced communications to make a 100,000 entity exercise possible. The Defense Simulation Internet is a product of our Communications and Data Flow project that makes possible the participation of the widely distributed simulation sites that you see on the viewgraph.

SYNTHETIC THEATER OF WAR

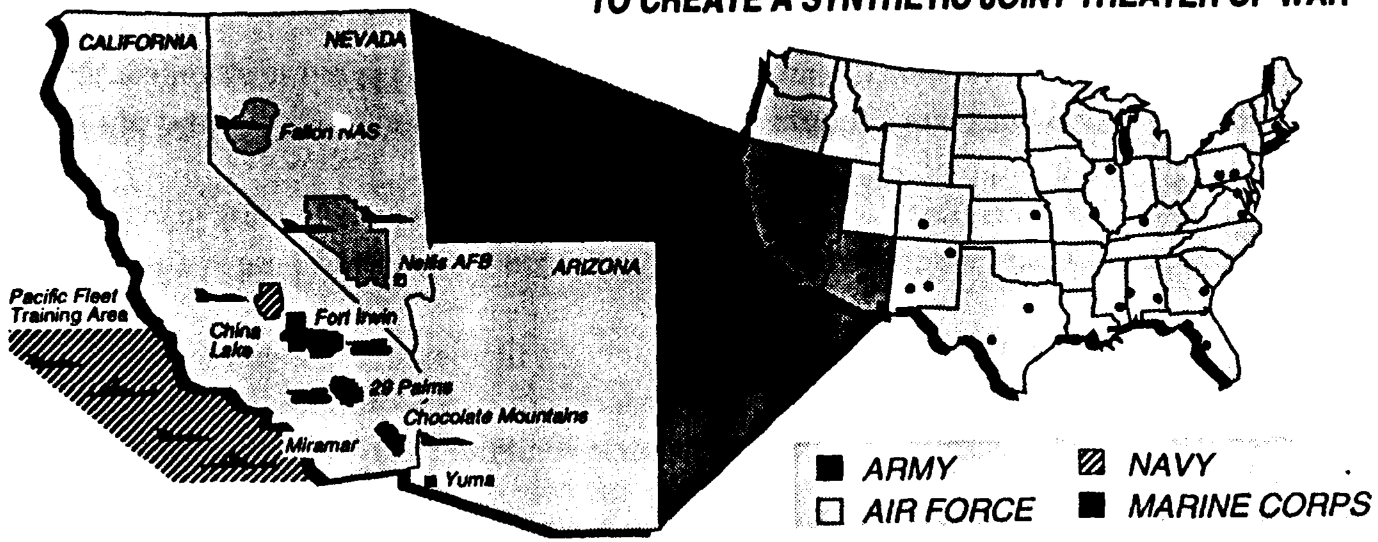
VISION

VIRTUAL, LIVE AND CONSTRUCTIVE FORCES LINKED TOGETHER TO PROVIDE A HIGH FIDELITY SYNTHETIC JTF ENVIRONMENT FOR REALISTIC TRAINING

APPROACH

DEVELOPMENT OF CORE TECHNOLOGIES TO ENABLE INTERCONNECTION OF SW TRAINING RANGES WITH JTF HEADQUARTERS AND SYNTHETIC FORCES

ADVANCED DISTRIBUTED SIMULATION AND INSTRUMENTED OPERATIONAL SYSTEMS TO CREATE A SYNTHETIC JOINT THEATER OF WAR



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VG 7 - Army National Guard

The goal of the Army National Guard program is to develop an experimental system that will yield a 200 to 300% increase in Reserve training efficiency. Since nearly one-half of our land combat power is provided by the Reserves, such a dramatic improvement will greatly enhance our readiness for the future.

A driving philosophy behind this concept is to move electrons, not people. Networked armories will be augmented with Local Area Networks, advanced simulators, "smart" command and control consoles, and communications facilities that will integrate local forces into battalion and brigade level exercises, effectively supplementing the National Training Center (NTC). The assertion is that troops trained in this fashion should achieve combat readiness at the NTC in a fraction of the current average requirement of 120 days.

The program approach is to network computer based instruction and enhanced simulation technology to create a new training test bed. This architecture will also serve as a model to foster exploitation of emerging technologies in developing breakthrough training tools and methodologies. The prototype systems will be operational in FY95.

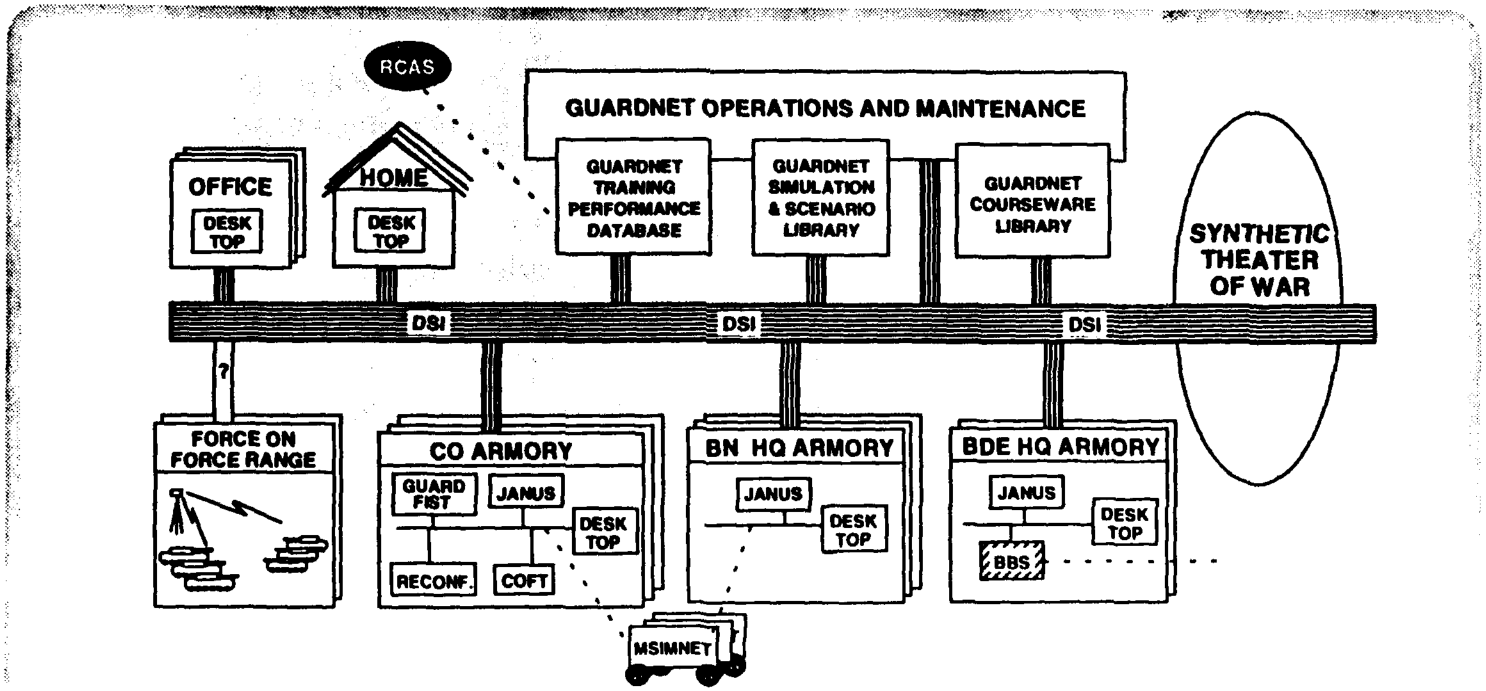
ARMY NATIONAL GUARD

VISION

TRAINING TOOLS FOR RESERVE FORCES THAT WILL DRAMATICALLY LEVERAGE THE LIMITED TIME AVAILABLE TO REACH FULL COMBAT READINESS

APPROACH

COMPUTER INSTRUCTION, RECONFIGURABLE AND MOBILE SIMULATORS, AND DISTRIBUTED, INTERACTIVE WARGAMING



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VG 8 - Rapid Planning and Deployment

The number one challenge to ultimately ensure our national security has been cited by Secretary of Defense Aspin as "Preserving the readiness of our armed forces to ensure the ability to quickly reach and successfully confront regional threats." As forward deployment is replaced by the concept of forward presence, the challenge of quickly deploying assets to insure a decisive victory becomes more and more difficult.

This challenge is being addressed through consideration of three specific efforts. First, as we look to the future, out ability to understand current situations and forecast future events will form the basis of our ability to effectively plan and deploy our forces, whether for counter proliferation, relief effort, peacekeeping, or warfare. Therefore, superb situational awareness is a major initiative within almost all of our activities. Second, we are looking at new, innovative tools for campaign planning which will facilitate not only coordinated planning by dispersed staff elements, but also the updating of plans as new information is received and the campaign situation evolves. The third element of the triad is a reexamination of our thinking about the best ways to accomplish the deployment of assets from prepositioned locations to their final destination. Studies have been initiated to consider the total transportation cycle and the identification of leverage points where technology can have significant impact.

By combining significantly improved situational awareness and rapid campaign planning with the proven value of prepositioned heavy lift military equipment, readiness can be significantly improved to achieve fast response for disaster relief and threats to national security.

RAPID PLANNING AND DEPLOYMENT

ARPA

VISION

MAXIMIZE PROBABILITY OF VICTORY IN CONFLICT THROUGH THE SYNERGISM OF SUPERB SITUATIONAL AWARENESS, ENHANCED CAMPAIGN PLANNING, PREPOSITIONING AND SIGNIFICANTLY IMPROVED DEPLOYMENT

SITUATIONAL AWARENESS

SURVEILLANCE, TRACKING DATA FUSION AND CORRELATION, AND C^3I STUDIES

CAMPAIGN PLANNING

INNOVATIVE CONCEPTS FOR JOINT/COMBINED FORCES DEPLOYMENT

TRANSPORTATION STUDIES

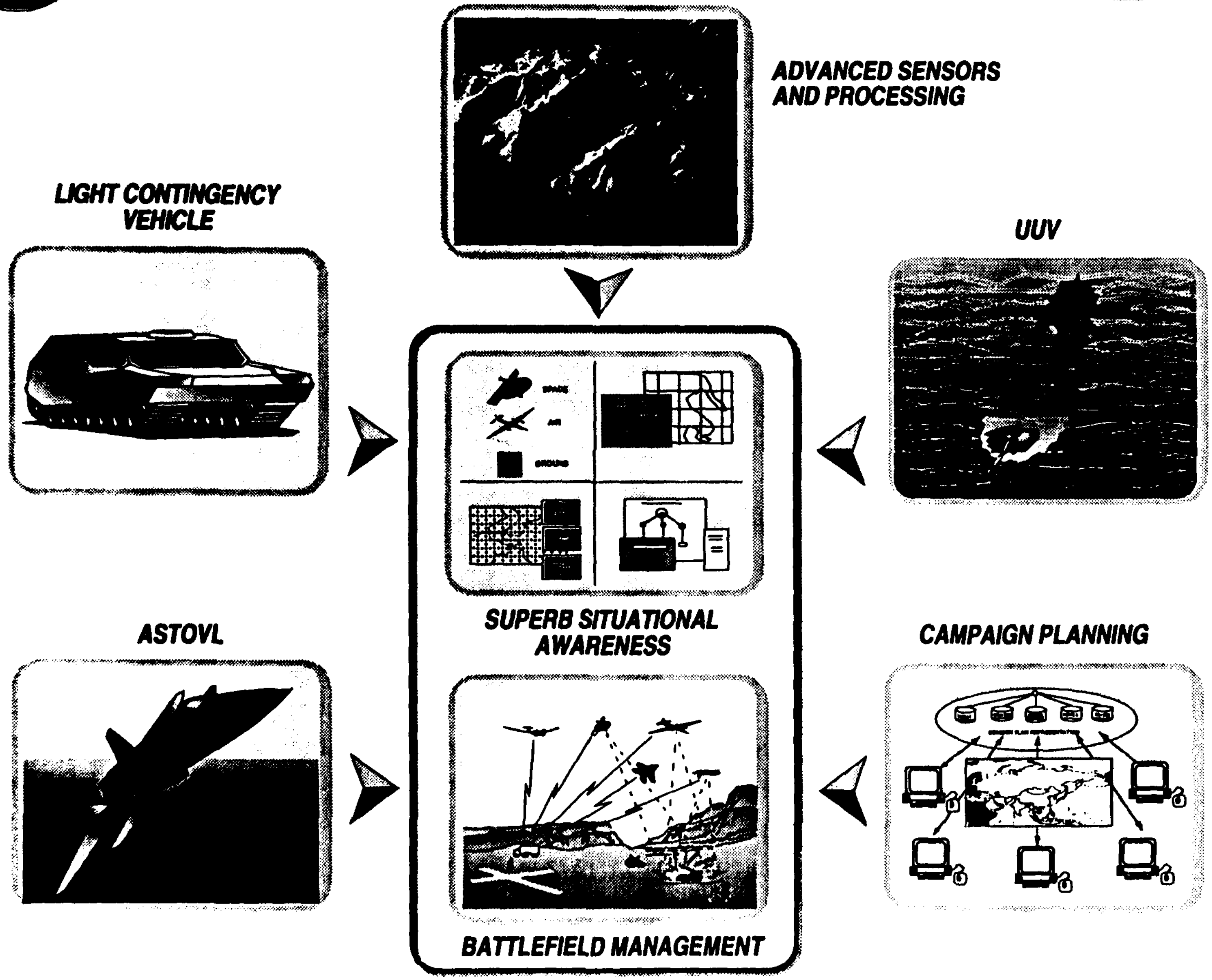
- AIR
- FAST SHIP
- WING SHIP

0264-93

VG 9 - Innovative Systems

Over the past two years, as we have attempted to define the technologies that will provide more effective joint warfighting capability at significantly reduced cost, several innovative military systems have emerged. Shown here are systems that we believe can provide a paradigm shift in the way the DoD conducts military operations. We are focused on systems that can contribute to significant improvement in Battle Management and help provide Superb Situational Awareness. You will hear about all of these systems in our classified session on Thursday; however, I would like to briefly summarize these efforts for you now.

INNOVATIVE SYSTEMS



0269-93

VG 10 - ASTOVL

Our Advanced Short Takeoff Vertical Landing (ASTOVL) fighter demonstration program has two primary goals. First is a "traditional goal" -- to demonstrate through flight testing that a common replacement for the F-18, F-16, and AV-8 fighter/attack aircraft is feasible. The second goal is to show that military aircraft can be made more affordable through innovative design development, manufacturing, and management techniques that can be employed to dramatically reduce the cost of aircraft.

The program is being conducted using a phased approach to first, validate critical technology; then, design and fabricate two full scale technology demonstrator aircraft; and, finally, full flight test of the demonstrator aircraft. The emphasis in the current Critical Technology Validation phase is to validate critical propulsive lift system technologies, perform manufacturability demonstrations, and mature the demonstrator aircraft design.

We are focused on demonstrating that both performance and cost goals are achievable before embarking on an expensive Engineering, Manufacturing and Development (EMD) project. Among the processes being explored are the use of inexpensive, "soft", throw away tooling and the lean production techniques so successfully employed by the automobile industry. We are considering the use of distributed simulation to help validate perceived performance requirements and are collaborating with the services to avoid locking in on performance specifications before proving the requirement to do so.

VG 11 - Light Contingency Vehicle

Heavy forces are survivable but take too long to deploy. Light forces are rapidly deployable but less survivable. The goal of the Light Contingency Vehicle (LCV) program is to develop the technologies to enable survivable light-weight lethal forces that can be sustained in half the time with half the transport assets. The LCV program will develop and demonstrate light-weight, survivable, deployable platforms in light to medium classes to support fielding of future Army and Marine Corps vehicles.

We are currently considering the following technologies for a two-man scout or weapons carrier:

- multi-spectral signature management (thermal, visual, acoustic, RF) for enhanced survivability,
- advanced sensor arrays for autonomous target detection, navigation and position location, and IFF confirmation for improved battle management capability,
- light weight composite structures for helicopter and air drop requirements in contingency operations,
- advanced propulsion and suspension systems for mobility and evasiveness to enhance survivability.

This rapid contingency concept enhances all Service mission requirements. It provides survivable and lethal ground forces for the Army and Marine Corps, eases transportability and deployability requirements for the Air Force and Navy, and allows the U.S. to respond quickly anywhere in the world against all threats (light to heavy).

ADVANCED SHORT TAKEOFF, VERTICAL LANDING (ASTOVL) TECHNOLOGY DEMONSTRATION

ARPA

VISION

A COMMON AFFORDABLE LIGHTWEIGHT FIGHTER AIRCRAFT FOR THE NEXT CENTURY

APPROACH

DEVELOP AND DEMONSTRATE PROPULSIVE LIFT SYSTEM AND MANUFACTURING TECHNOLOGIES TO PERMIT LOW RISK INITIATION OF AFFORDABLE ASTOVL DEVELOPMENT

0272-93

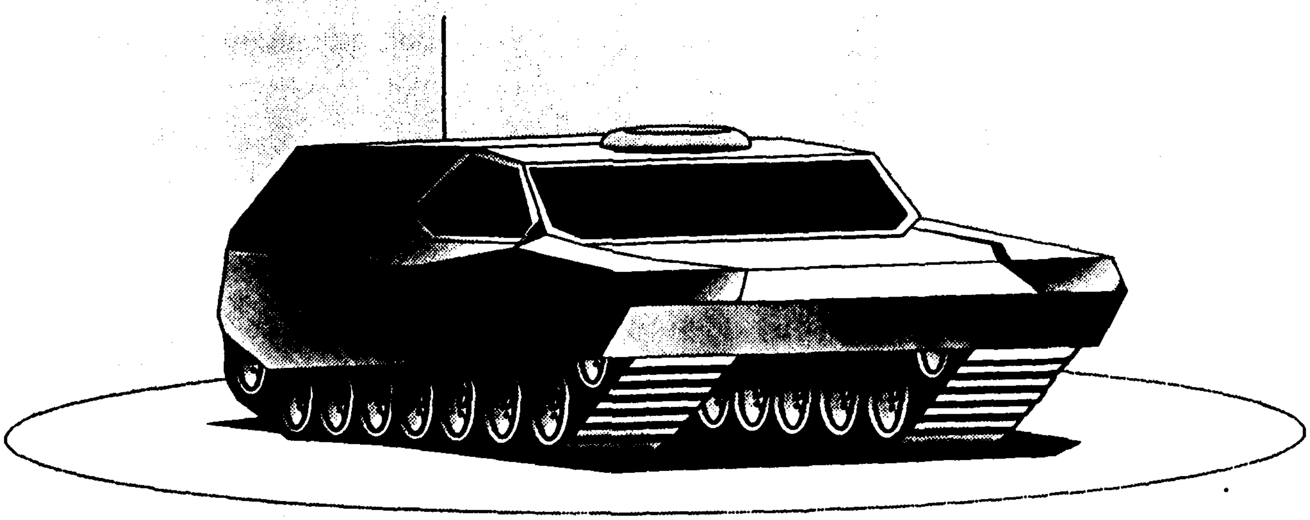
LIGHT CONTINGENCY VEHICLE (LCV)

VISION

MORE RAPID PROJECTION OF LIGHTWEIGHT LETHAL FORCES WITH FEWER RESOURCES (VEHICLES AND PERSONNEL)

APPROACH

DEVELOP LIGHTWEIGHT, SURVIVABLE, DEPLOYABLE, LETHAL VEHICLES FOR SCOUT AND COMBAT MISSIONS



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VG 12 - CAMEO

The CAMEO program will integrate advanced optical and sensor technologies to demonstrate and space-qualify a new, lightweight multispectral remote sensing small satellite. The program offers an important two-fold opportunity: (1) to demonstrate technology that simultaneously addresses critical civil and DoD needs; and (2) to advance the concept of using small satellites for rapid, affordable capability insertion beyond DoD, into the civil/national space arena.

The goals of the program are to demonstrate:

- dual-use, multi-purpose advanced remote sensing technologies for wide area surveillance, global climate research and environmental monitoring;
- the use of small satellites to rapidly augment on-orbit capability and affordably modernize both DoD and civil remote sensing satellite constellations; and
- new payload operational concepts and the direct downlinking of usable data to DoD and civil customers.

The payload concept is distinctly different from typical "dual-use" approaches. Rather than develop a sensor that can only be used for a single purpose by "dual-users" (for example, cloud imaging for DoD and civil needs), this program will develop advanced sensor technology adaptable to multiple purposes by multiple users.

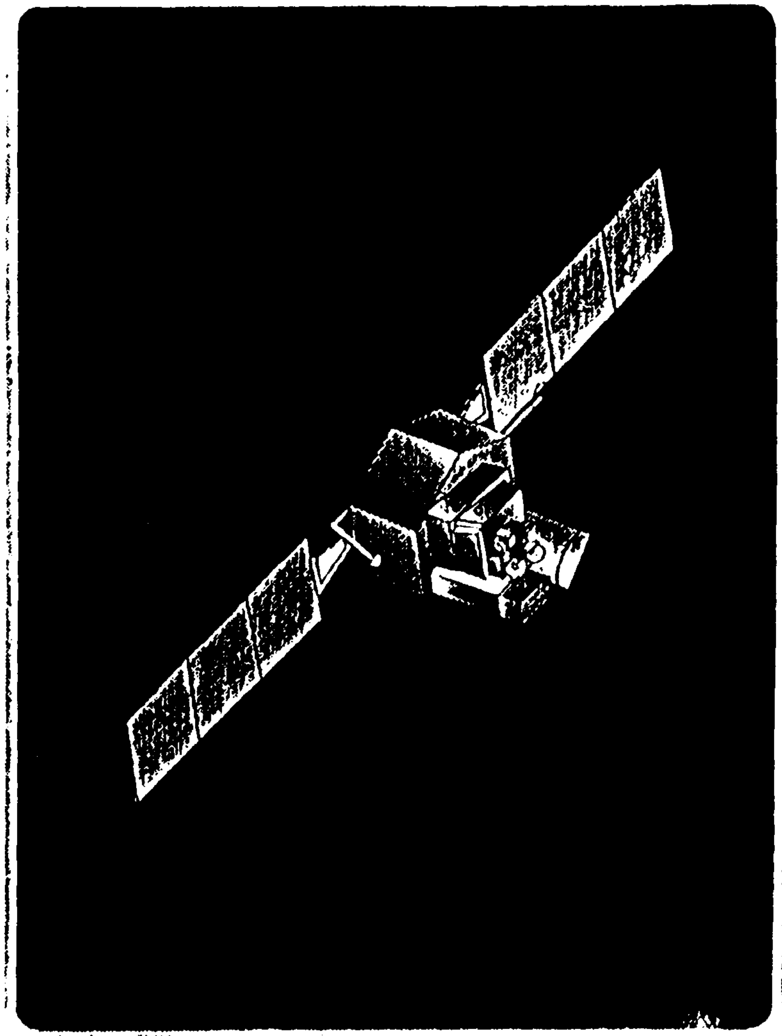
CAMEO

VISION

TACTICAL WIDE AREA SURVEILLANCE AND GLOBAL ENVIRONMENT MONITORING AND CLIMATE RESEARCH

APPROACH

DEVELOP AND DEMONSTRATE ADVANCED MULTISPECTRAL TECHNOLOGIES AND VALIDATE AFFORDABLE SPACE ACQUISITION



VG13 - Multiple Sensor Target Recognition System (MUSTRS)

Major shortfalls in Desert Storm SCUD-hunt operations were the surveillance, targeting and prosecution of mobile time-critical targets (TCTs).

ARPA's MUlti-Sensor Target Recognition System (MUSTRS) Program, previously known as THIRSTY SABER, focuses on the surveillance, targeting, and prosecution of mobile TCTs.

MUSTRS is a multi-sensor targeting testbed comprised of a multi-mode millimeter wave (MMW) radar and second generation forward-looking infrared (FLIR) camera slaved to precision gimbal systems. High speed signal processors condition and fuse the derived data from these sensors in near-real time to yield high probability of target recognition ($P_r > 0.7$) at a low false alarm rate (FAR < 0.01 FA/Sq-Km). This generic targeting system can be configured for use in most air-breathing platforms, but has been associated, until recently, with cruise missile applications because of its potential autonomous system operation. Recent assessments of the MUSTRS algorithm suite, using real MMW and FLIR data, indicate that MUSTRS' projected target detection/recognition performance is achievable. The sensor testbed is scheduled for completion in early FY94, and will begin a number of detailed field experiments to validate its projected systems performance.

MUSTRS could provide a significant targeting improvement to various U.S. weapon and reconnaissance platforms.

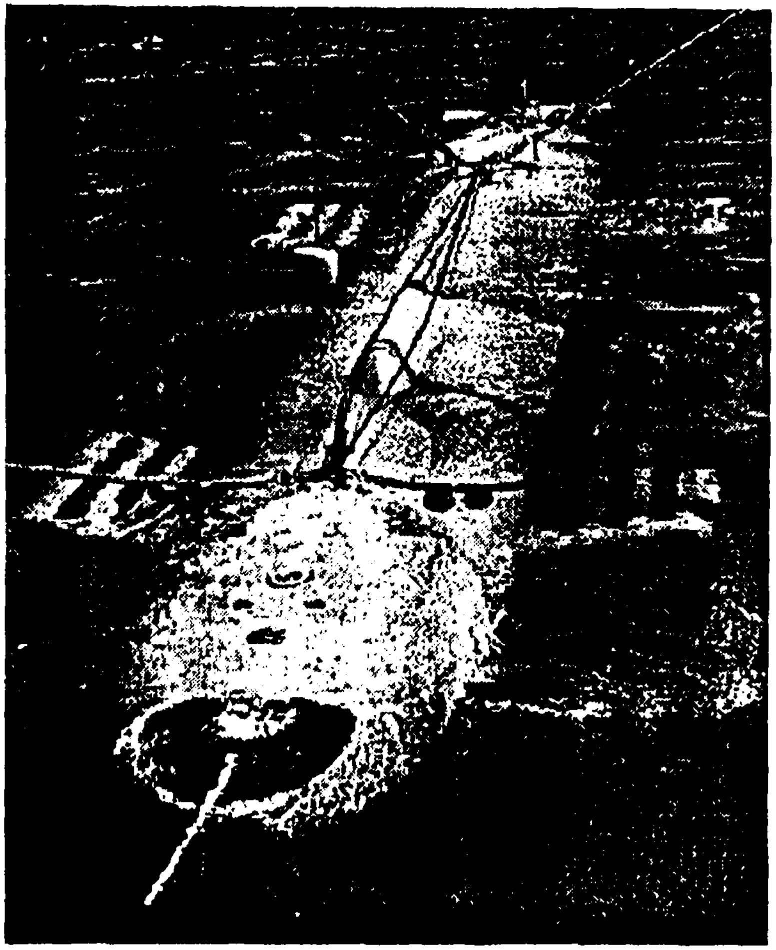
UNMANNED UNDERSEA VEHICLE (UUV)

VISION

INCREASED SHALLOW WATER SURVIVABILITY AND EFFECTIVENESS IN STRATEGIC AND LIMITED OBJECTIVE WARFARE SITUATIONS

APPROACH

DEVELOP AND DEMONSTRATE AUTONOMOUS MARITIME SYSTEMS FOR NEAR LAND WARFARE



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VG 14 - IFSAR

We are also investigating the next generation capability beyond MUSTRS in our interferometric synthetic aperture radar (IFSAR) program.

IFSAR refers to creating three dimensional pictures from normal two-dimensional synthetic aperture radar (2D SAR) images. In other words, IFSAR adds a depth perspective to "flat" 2D SAR images. IFSAR potentially can provide a quick response digital terrain elevation (DTE) map, or a three dimensional image of a potential TCT. This effort emphasizes both low cost scene generation, as well as robust system performance.

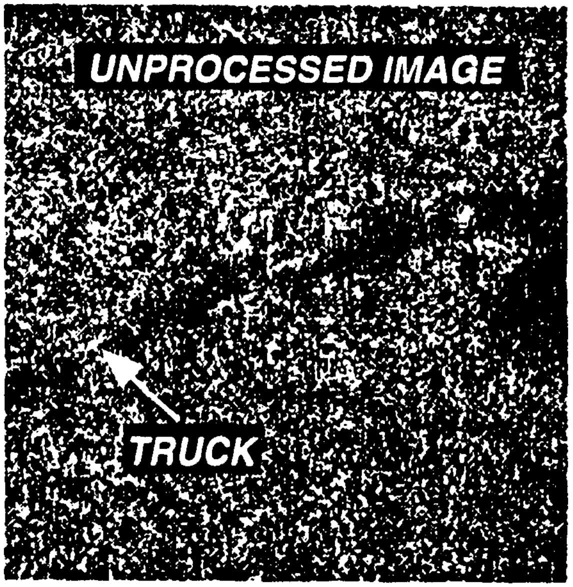
The IFSAR testbeds currently being developed for ARPA are expected to generate high quality DTE images at a rate of 100 square-kilometers per minute or better. This information is used in establishing superb situational awareness.

The picture at the bottom of the viewgraph illustrates a color-coded-in-height IFSAR image (bottom) produced by the CALTECH Jet Propulsion Laboratory. The terrain pictured is one of a pre-surveyed section of the National Training Center, FT Irwin. In a separate investigation, ARPA is assessing the feasibility of detecting and recognizing TCTs in man-made and natural clutter using IFSAR imagery.

ULTRA-WIDEBAND RADAR

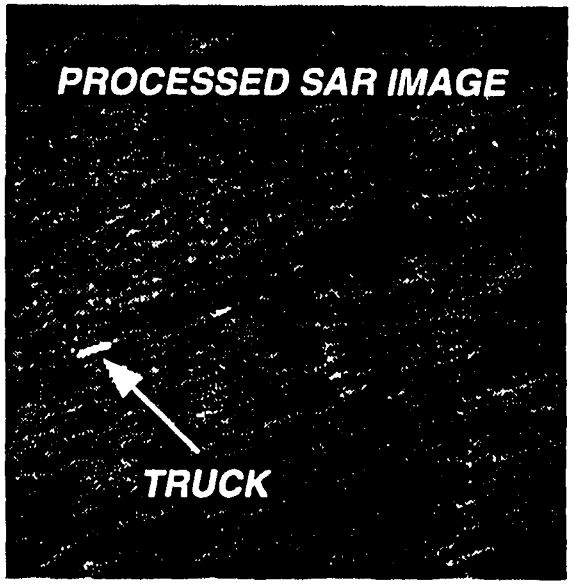
OBJECTIVE

EXPLOIT THE COMBINATION OF FOLIAGE PENETRATION BY LONG WAVELENGTHS AND HIGH RESOLUTION (WIDE BANDWIDTHS) FOR DETECTION OF TCTs IN DEEP HIDE



APPROACH

- CONTINUING EXPERIMENTS AND DATA COLLECTION TO SUPPORT DESIGN OPTIMIZATION AND ALGORITHM DETECTION
- INITIATION OF LOW COST RADAR PROGRAM



VG 15 - Ultra-Wideband Radar

Finding targets in deep hide, especially time critical targets (TCTs) presents a challenge we are only beginning to meet. The Ultra-Wideband (UWB) radar is one promising technology. ARPA has managed the ARPA/BTI UWB Radar Program for the past several years. The intent of the initial phase of the program was to explore UWB technology and determine those radar applications where it offered a significant advantage over conventional approaches. The combination of long wave lengths (low frequencies) for their ability to penetrate and wide absolute bandwidth for high resolution automatically defines radars of this type as being UWB and the initial phase demonstrated the practicality and performance potential of such designs. UWB has an advantage over other radars intended to image targets through obscuration such as camouflage and foliage.

Our current approach is to execute an extensive series of experiments and data collection exercises with the goal of understanding the relevant phenomenology and radar performance factors, and to support the development of target detection algorithms for this unique class of radars. There is currently no single instrumentation radar to support such research so a variety of platforms are being used in the program. All of these platforms operate at L-band or lower frequency and have resolutions ranging from a few to less than one meter. The photographs show one meter resolution data from the SRI UWB platform, before and after processing.

We are currently launching the low cost UAV Radar Program where one of the needed modes will be for the detection of targets in hiding and will likely be UWB.

INTERFEROMETRIC (3-D) SAR

VISION

LOW COST, QUICK RESPONSE
DIGITAL TERRAIN AND
TARGET ELEVATION MAPPING

APPROACH

DEVELOP AND DEMONSTRATE
LOW COST 3-D MAPPING
CAPABILITY USING SYNTHETIC
APERTURE RADAR

VG 16 - Unmanned Undersea Vehicle

The shift in the Navy's primary thrust from that of a blue-water power projection force to that of a littoral force emphasizes the need for systems that are affordable and can provide support for near land warfare. An Unmanned Undersea Vehicle (UUV) can perform many potential supporting missions affordably. Under ARPA's UUV project we are developing and demonstrating fully autonomous maritime systems that can detect and neutralize enemy mines and deploy surveillance systems.

Enemy mines present a significant threat to U.S. operations in coastal areas where surface and air mine sweeping operations are not feasible. A UUV that can detect and neutralize enemy mines would allow a surface ship or submarine to penetrate mined waters with a high degree of safety not currently available without time consuming mine sweeping operations. Deployable surveillance systems are intended to demonstrate an antisubmarine warfare surveillance mission for UUVs.

We are currently developing enabling UUV technologies to perform these two missions along with other stressing maritime missions. Specifically, research is being conducted in high energy density fuel cell power to replace the batteries currently used for UUV propulsion, high precision inertial navigation systems, acoustic communications for reliable communications between a UUV and its host platforms, advanced sensor systems, and underwater mapping technologies.

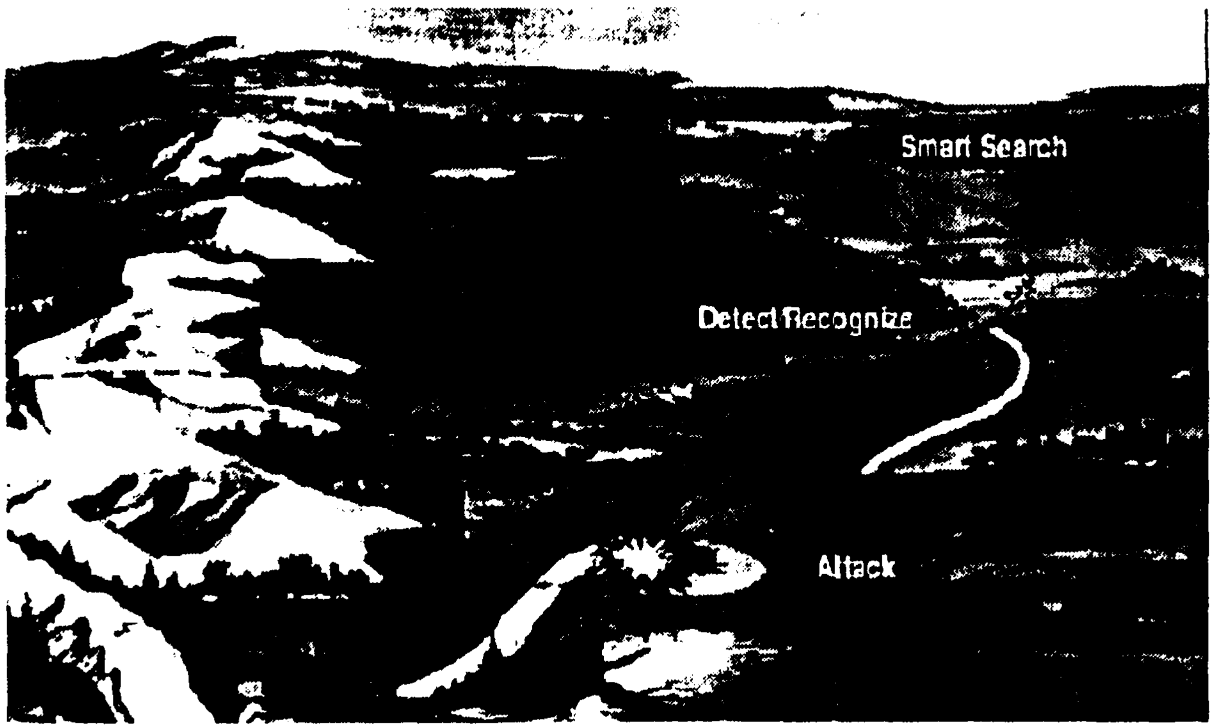
MULTISENSOR TARGET RECOGNITION SYSTEM

VISION

DEVELOP ATR PROCESSING AND SENSOR TECHNOLOGIES TO SEARCH FOR, RECOGNIZE, AND LOCATE TIME CRITICAL TARGETS

APPROACH

- MULTISENSOR FUSION
  - 2nd Generation IR
  - MMW Radar
- ALGORITHM DEVELOPMENT
  - Model Based Target Recognition
  - Sensor Fusion/Evidence Accumulation
- DESIGN AND DEMONSTRATIONS



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VG 17 - Campaign Planning

Beyond our programs to develop and demonstrate military hardware, we are also investing in several innovative software systems.

The unprecedented complexity of the daily air battle planning requirements of Desert Storm demonstrated the need for and value of enhanced campaign planning that will assist the joint commander's senior planner to build, maintain, and communicate the campaign plan. The capabilities to be achieved should also better enable him to consider alternatives and maintain real-time the underlying assumptions, which change frequently, and further enable him to interface and interoperate with operational and intelligence databases and models.

Our first initiative to address this goal is to conduct a demonstration of a functional prototype that embodies the Air Campaign Planning Model, which was so successful in Desert Storm. The demonstration will take place during this year's Red Flag exercise. The prototype will enable a "joint" Forces Air Campaign Coordinator to conduct air campaign planning, air battle planning and mission planning and execution. He will be able to methodically model and analyze the opponent, formulate a plan to defeat him, apply available assets, conduct the campaign, and respond to contingencies and opportunities. Successful demonstration of this prototype may lead to an early transition to the Air Force. Following this quick reaction proof of principle, the logical next step is integration into the Air-Land Battle Doctrinal Concept followed by full utilization of enhanced campaign planning tools in all phases of the air-land-sea battle.

CAMPAIGN PLANNING

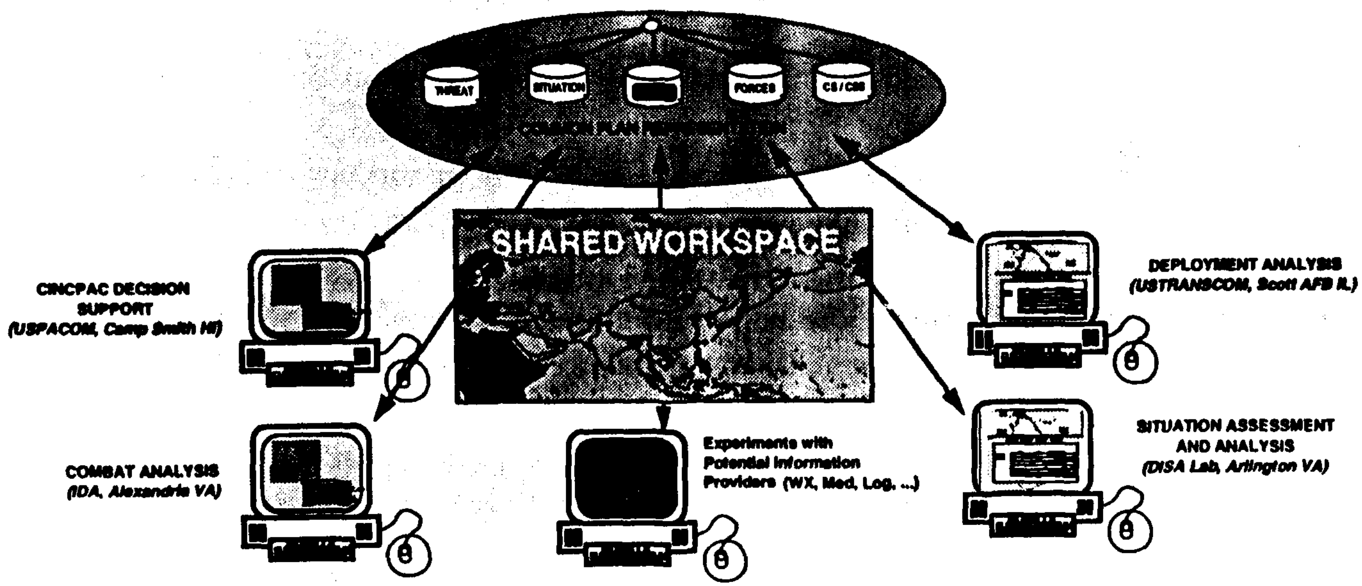
VISION

ENHANCED CAMPAIGN PLANNING TO ENABLE THE RAPID CONSTRUCTION, MAINTENANCE AND COMMUNICATION OF THE OPTIMAL PLAN

APPROACH

DEMONSTRATE EFFECTIVE AIR CAMPAIGN PLANNING AND EXPAND TO AIR-LAND BATTLE DOCTRINAL CONCEPT

FY93 Distributed, Collaborative Crisis Action Planning Experiments



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VG 18 - Superb Situational Awareness

Superb situational awareness is the cornerstone of future military operations.The development of technologies to provide superb global situational awareness for decision makers spans the spectrum from the information sources to automated interpretation functions. Advance sensors coupled with robust automated detection and classification technology provide the raw data. This data is correlated and compared with process models that can rapidly adapt to individual situations. The core information processing technology being pursued by ARPA to provide this capability includes message handling systems to extract information from free text, automated status assessment approaches to quantify the red force disposition and robust sensor/information correlation algorithms to fuse target related information.

Two critical areas of application are ARPA's War Breaker Program (precision strike against Time Critical Targets) and Counter Proliferation Initiative.

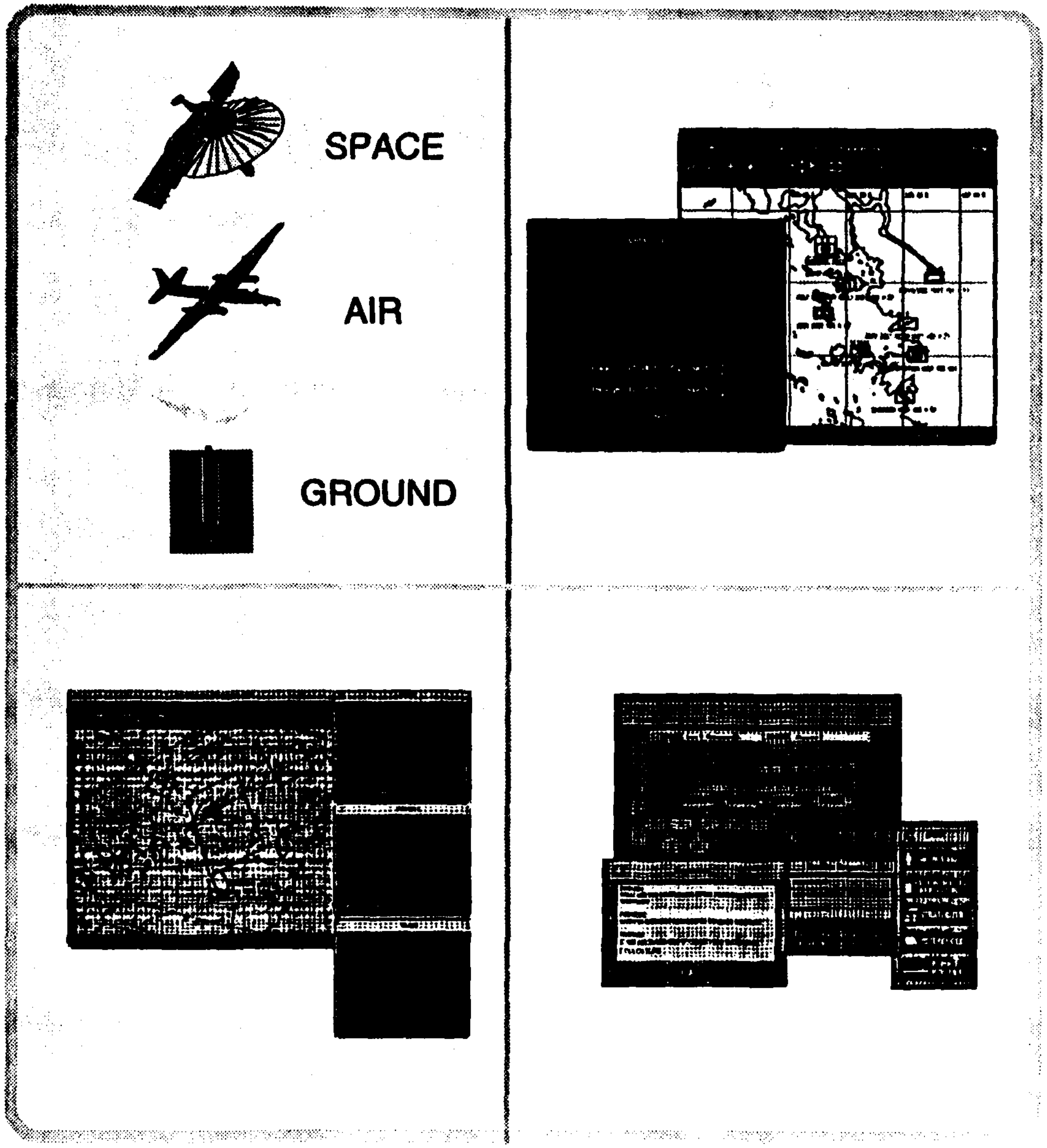
SUPERB SITUATIONAL AWARENESS

VISION

COMPLETE, ACCURATE AND TIMELY LOCATION OF AND IDENTIFICATION OF ALL FRIENDLY AND HOSTILE ELEMENTS WITHIN THE THEATER OF CONFLICT

APPROACH

INTEGRATE SPACE-AIR-GROUND SURVEILLANCE SENSORS; AUTO DETECTION AND CLASSIFICATION; AUTOMATED CORRELATION; AND MESSAGE HANDLING SYSTEMS



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VG 19 - Battlefield Management

The battlefield is the ultimate essence of war and is the most unpredictable. Improving battle management offers probably the biggest force multiplier. To quote General Norman Schwarzkopf, "the analysts write about war as if it's a ballet, like it's choreographed ahead of time, and when the orchestra strikes up and starts to play, everyone goes out there and plays a set piece. What I always say to those folks is, 'Yes, it's choreographed, and what happens is the orchestra starts playing and some son-of-a-bitch climbs out of the orchestra pit with a bayonet and starts chasing you around the stage."

My interpretation of what the General is saying is that you do your best to get ready, but plan for surprises. You must have the ability to rapidly adjust and to communicate those adjustments to the forces at all levels.

Our vision is to bring innovative technologies into being that will give the battlefield commander the best possible operational planning tools, the best possible situational awareness, and the best possible C^3 mechanisms for his assigned forces. All of the advanced sensors, the Advanced Distributed Simulation Environments, the intelligence fusion, the planning tools, and the innovative systems are all focused toward maximizing the odds in favor of our commander toward achieving victory with the minimum possible casualties.

BATTLEFIELD MANAGEMENT

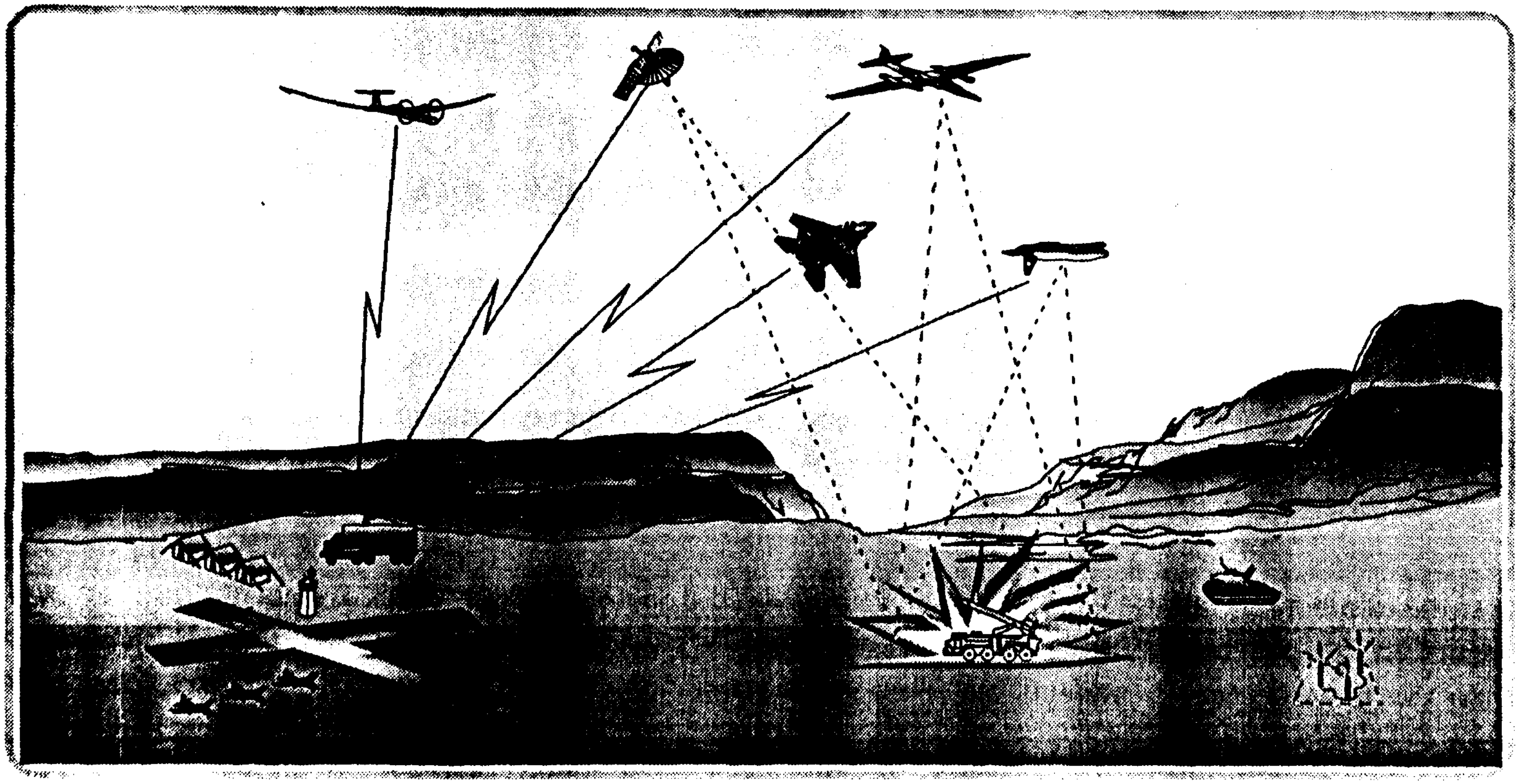
ARPA

VISION

EXPLOIT OUR BEST OPPORTUNITY FOR FORCE MULTIPLICATION

APPROACH

RAPIDLY ADAPTABLE PLANNING, SUPERB SITUATIONAL AWARENESS, AND ENHANCED C^3



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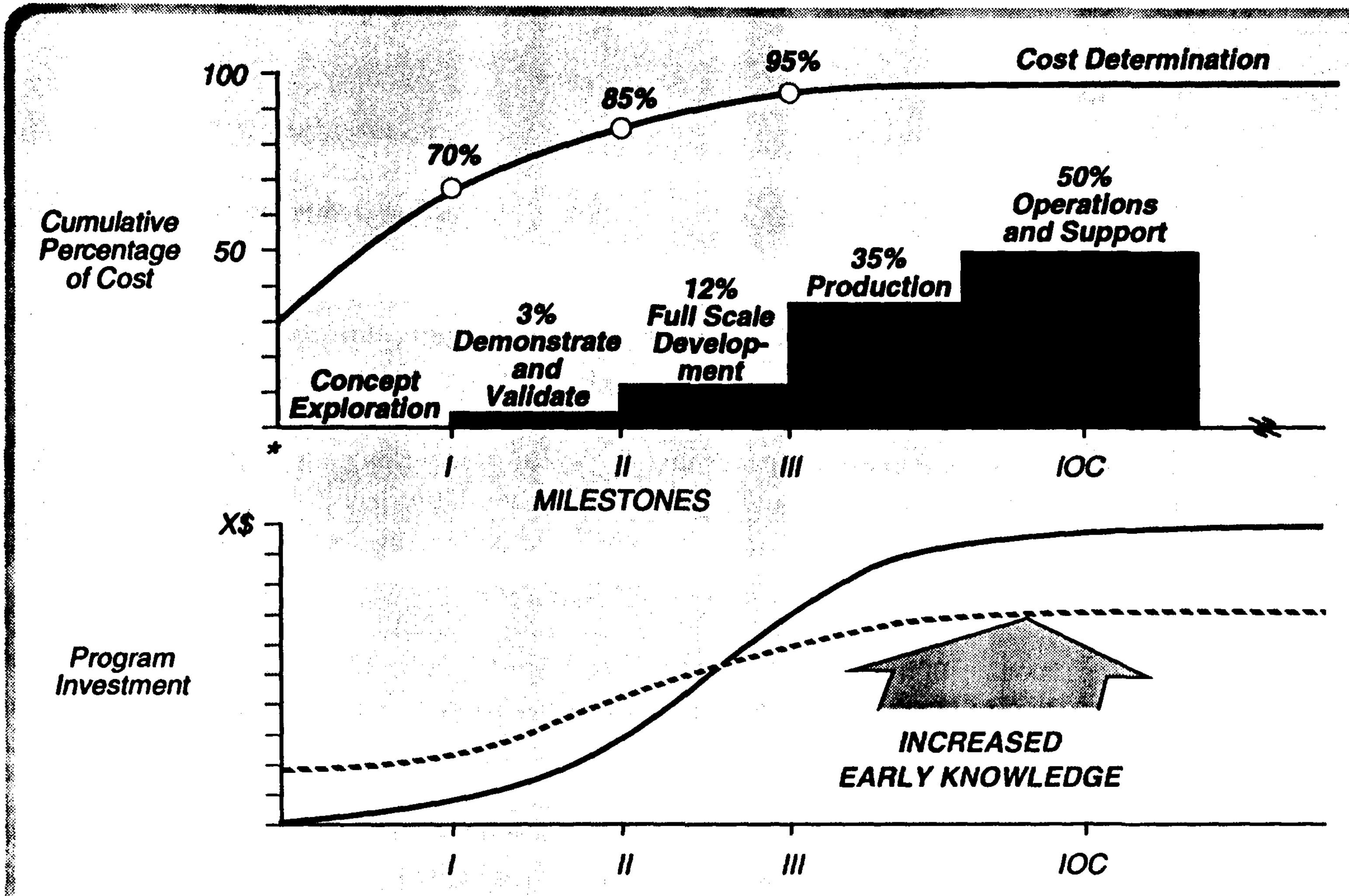
VG 20 - Life Cycle Cost Commitment

As I mentioned earlier, affordability is the operative word across all of the dimensions that I have discussed. Unfortunately, DoD historical data and conventional wisdom show that the majority of the total life cycle costs of a system are determined in the beginning phases of program development where both the level and maturity of total systems knowledge are minimal.

If technology and methodology could be developed to address thorough system definition, production and operations at the front-end of a program and if we could evaluate the resulting systems in a warfighting-like environment, it should be possible to significantly drive down the life cycle cost through developing more responsive and meaningful requirements, highly effective systems, and innovative operational concepts.

Combining integrated product and process development engineering methods with Advanced Distributed Simulation technologies will offer the opportunity to learn how to quickly gain and apply up-front systems knowledge to build capable systems more affordably and in less time.

TYPICAL SYSTEM LIFE CYCLE COST COMMITMENT



EARLY KNOWLEDGE OF SYSTEM DEFINITION, PRODUCTION AND OPERATION IS CRITICAL TO AFFORDABILITY

* SOURCE: Defense Systems Management College, May 1986

0281-93

VG 21 - Advanced Distributed Simulations

Depending on our background, we all have a different understanding of the word "simulation." To some, war game exercises like JANUS are simulations; to others, simulators represent simulation; to others, live exercises are simulation; however, we should keep in mind that anything less than war itself is simulation.

Advanced Distributed Simulation (ADS) is a synthetic environment containing constructive, virtual, live simulations where systems, organizations and people can meet to perform high fidelity joint exercises or processes. ADS is being expanded to include constituent elements which influence cost and performance of the systems, such as manufacturing, training, operations and systems engineering.

Today's Advanced Distributed Simulation is based on the Defense Simulation Internet which will be eventually folded into the concept of global communications grid. Advanced technologies now in development which will enable the expansion and enhancement of the use of Advanced Distributed Simulation are:

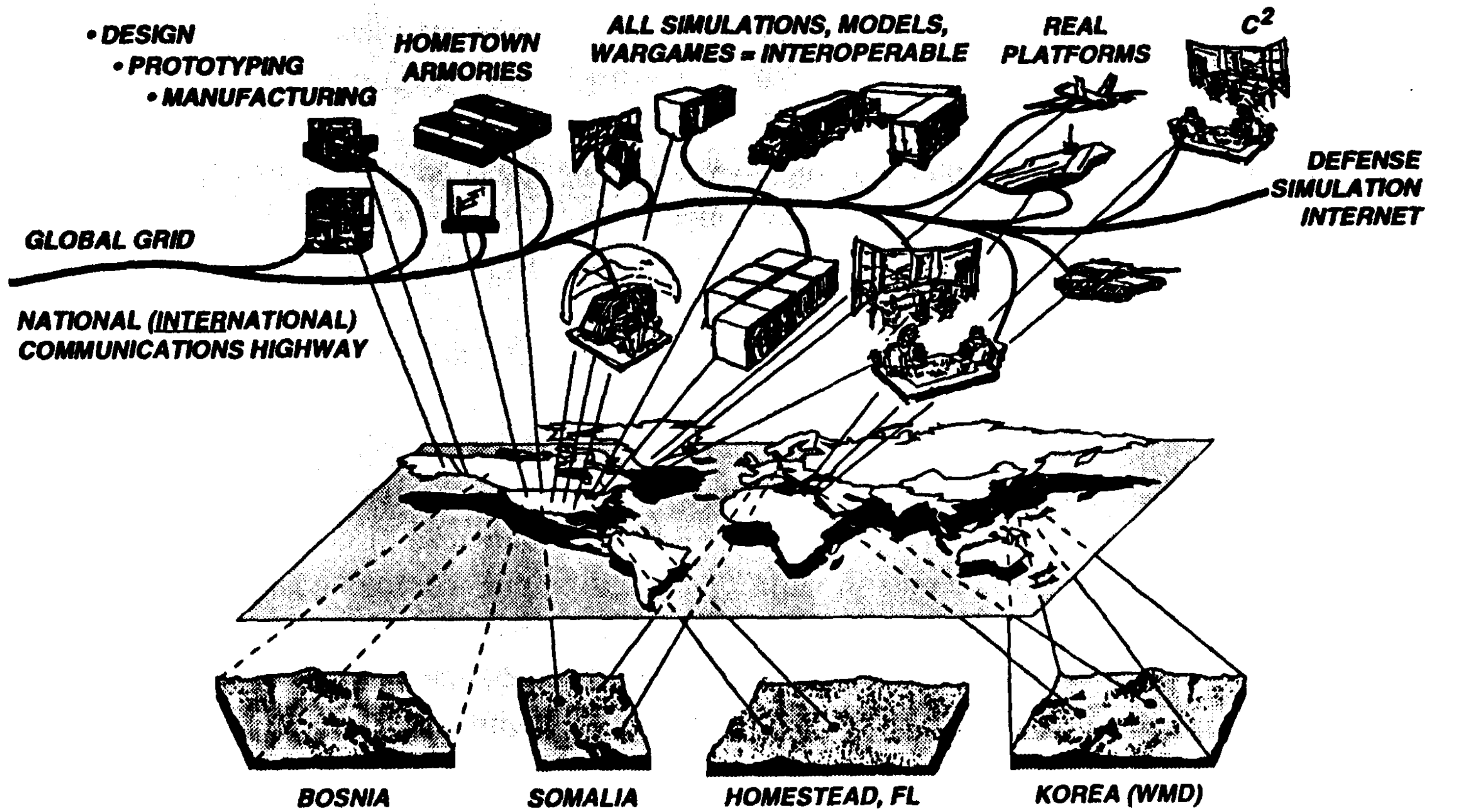
- Advanced Networking with Multiple Level Security
- Terrain Generation Models
- Environmental Models
- Computer-Generated Images
- Semi-Automated Forces
- Intelligence Gateways
- Heterogeneous Databases

ADVANCED DISTRIBUTED SIMULATION

ANTHING LESS THAN WAR IS SIMULATION
- LIVE
- VIRTUAL
- CONSTRUCTIVE

COST ELEMENTS

- ALL MAJOR COMMUNITIES INVOLVED
- DESIGN TRADES IN OPERATIONAL SITUATION
- FOCUS T&E ON CRITICAL ISSUES
- HUMAN/SYSTEM OPERATIONAL INTERFACES



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VG 22 - Operational Concepts

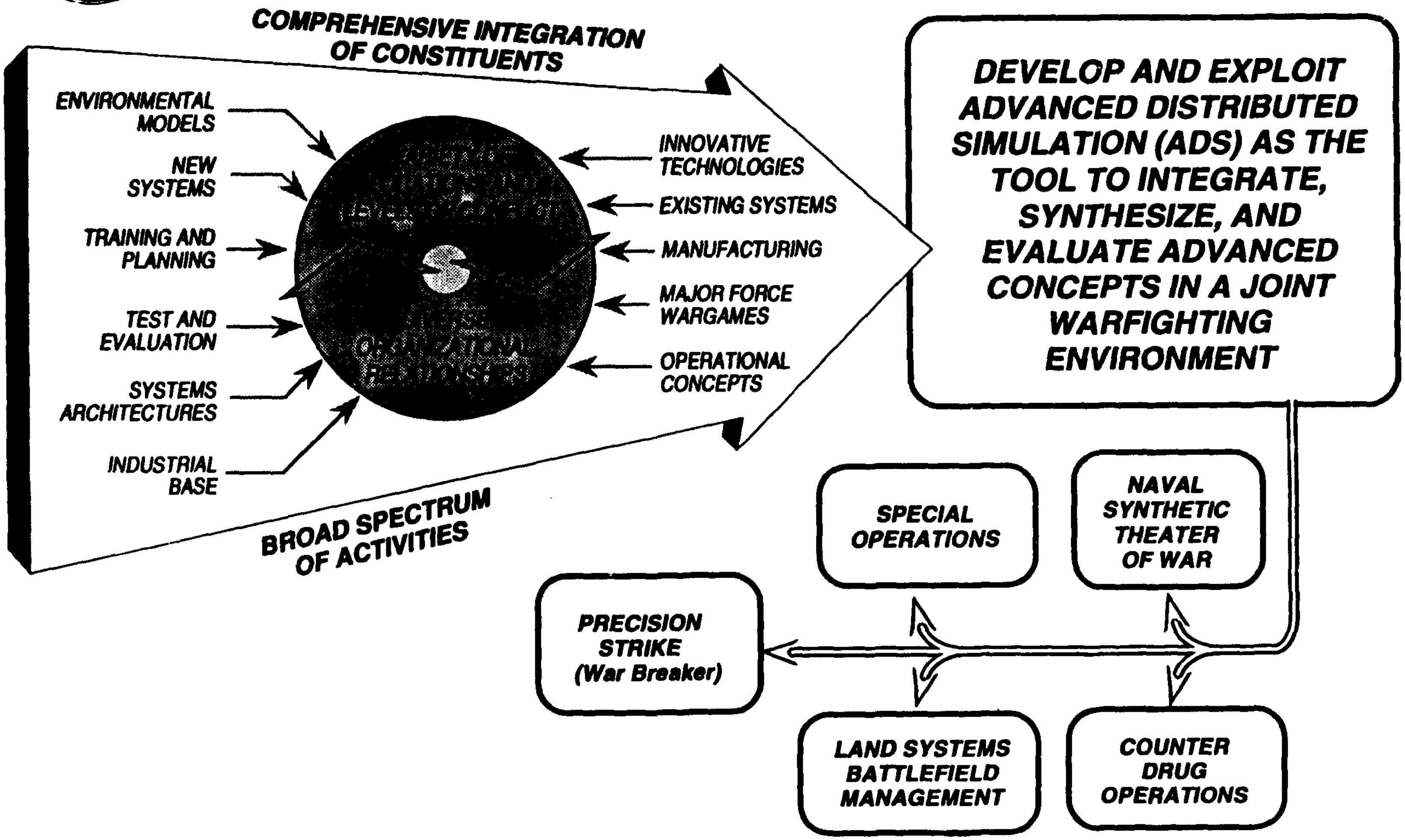
Exploiting Advanced Distributed Simulation technology into advanced systems engineering tools that provide a joint warfighting environment and enable a comprehensive understanding of operational and organizational relationships, innovative systems, and upper level cost and performance trades is the goal of this development. The concept brings users, technologists, and developers together to gain a rapid understanding of the "real" requirements while simultaneously providing a framework where C^3I, organizational alternatives, and innovative operational concepts can be evaluated, defined and refined across a broad spectrum of levels of conflict and geographic and environmental conditions. This goal should allow constituents to participate and support meaningful consideration and trades between the cost driving elements of performance, manufacturing, test and evaluation, reliability, transportation, etc.

Advanced Distributed Simulation, used as an advanced systems engineering tool, enables the fast attainment of better up-front requirements, to promote rapid, systematic and logical evolution of specifications. It hosts sensitivity trades of all cost driving elements, particularly the "ilities" and uses of commercial practices and products.

The examples depicted on the viewgraph are on-going areas where Advanced Distributed Simulation technology is being expanded and matured. The examples use Advanced Distributed Simulation to support systems engineering and trades, operations, training, and the evaluation of innovative and alternative concepts of operation.

Our most challenging program currently being pursued is the War Breaker program. I would like to show you a video tape of our first demonstration which was performed last year.

OPERATIONAL CONCEPTS



ADS PROVIDES MEANS TO BRING USERS AND DEVELOPERS TOGETHER, BUILD EARLY CONSTITUENCY FOR FASTER TECHNOLOGY TRANSITION, AND DEVELOP AND REFINE INNOVATIVE CONCEPTS OF OPERATION

0265-93

VG 23 - Affordability

Integrated Product and Process Development (IPPD) is the bringing together of all constituent elements that affect the cost and performance of a system as early as possible in the acquisition process. This enables concurrent development of the system, the manufacturing processes and the support systems, as well as supporting testers and evaluators and the early training of the operators and maintainers. Ideally, this would all be done in the earliest part of a program where the greatest impact can be made to drive total costs down.

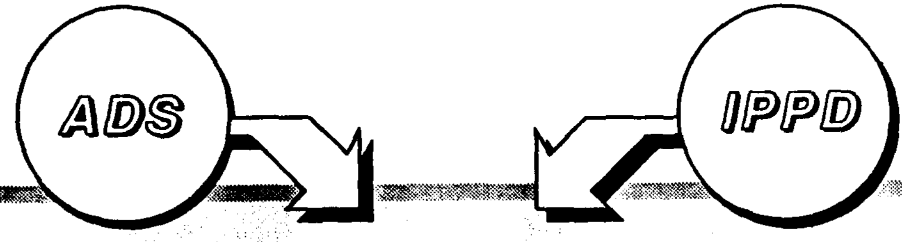
Until Advanced Distributed Simulation (ADS), no reasonable tools existed to facilitate the entire IPPD methodology. Certain knowledge-based computer-aided engineering tools, CAD, CAM, CAx, etc. attempted to solve portions of the IPPD interface but were very narrow and only allowed a few of the constituents to participate interactively.

Now Advanced Distributed Simulation technology has matured to the level where the constituent elements can be brought together in a synthetic warfighting environment, where all elements can participate and contribute within a single context. Through the exchange of data and the exercising and evaluation of the resultant military contribution to the overall warfighting capability at various levels of conflict, we can begin to measure and assess marginal cost of requirements and new technologies.

Expanding and exploiting Advanced Distributed Simulation technologies into advanced systems engineering tools provides the critical missing enabling technology to realize the full potential of the integrated product and process development methodology.

The use of Advanced Distributed Simulation for Advanced Systems Engineering and as the host and forum for data exchange among diverse constituent elements has already begun. A future where integrated product and process development is implemented through Advanced Distributed Simulation holds the promise of addressing "affordability" in quantifiable and measurable terms.

AFFORDABILITY



A NEW PARADIGM IN AFFORDABLE ACQUISITION

- MULTI-FUNCTIONAL TEAM INVOLVEMENTS
- SUPPLIER TEAMING
- EARLY PROCESS FOCUS
- QUALITY DESIGNED IN AND MEASURED
- INTEGRATED TOOLS (CA-"x")
- FLEXIBLE SPECIFICATIONS
- FLEXIBLE MULTI-USE FACTORIES
- PERFORMANCE/COST TRADES AT HIGH LEVELS
- CONTINUOUS CUSTOMER INVOLVEMENT

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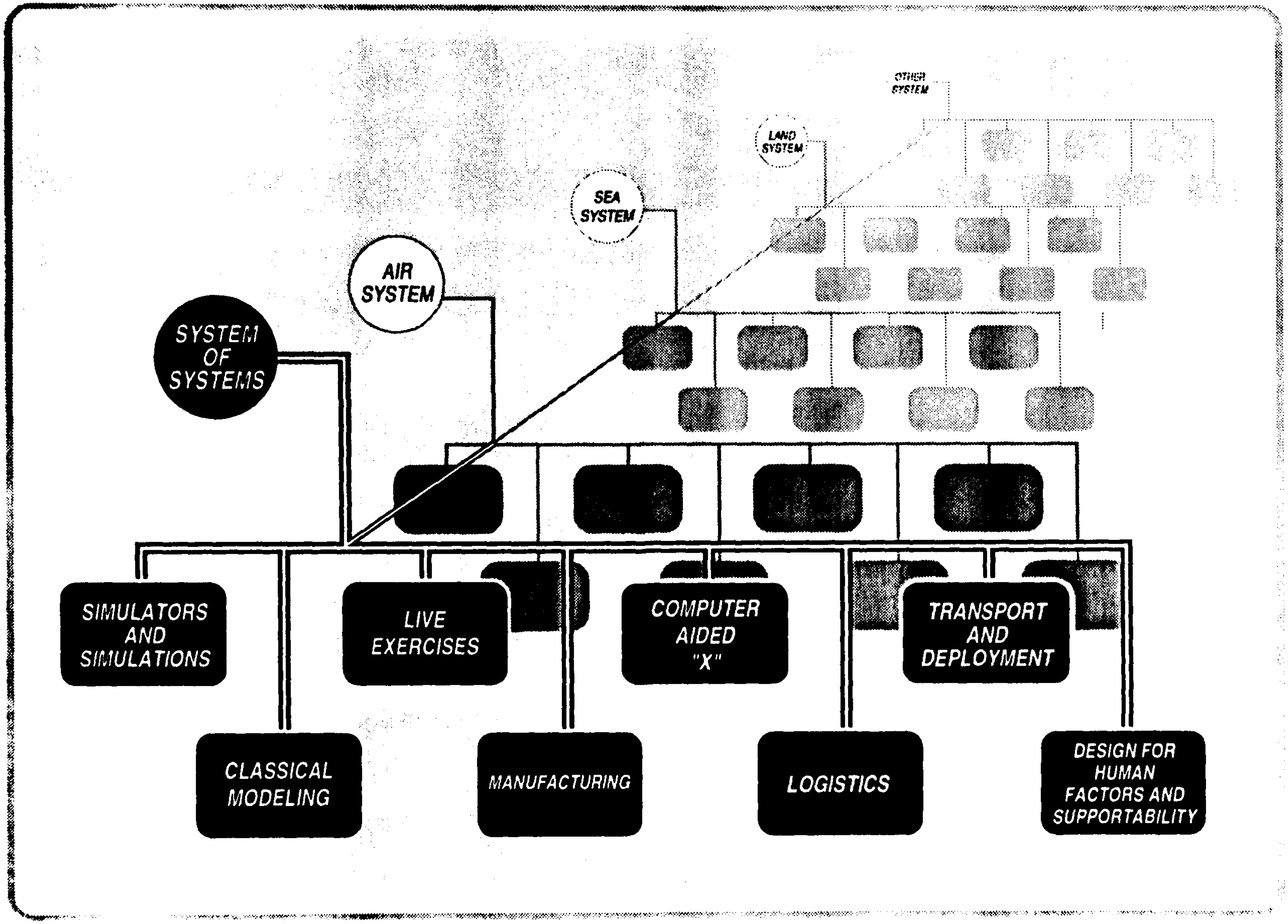
ADS/IPPD FOR ACQUISITION



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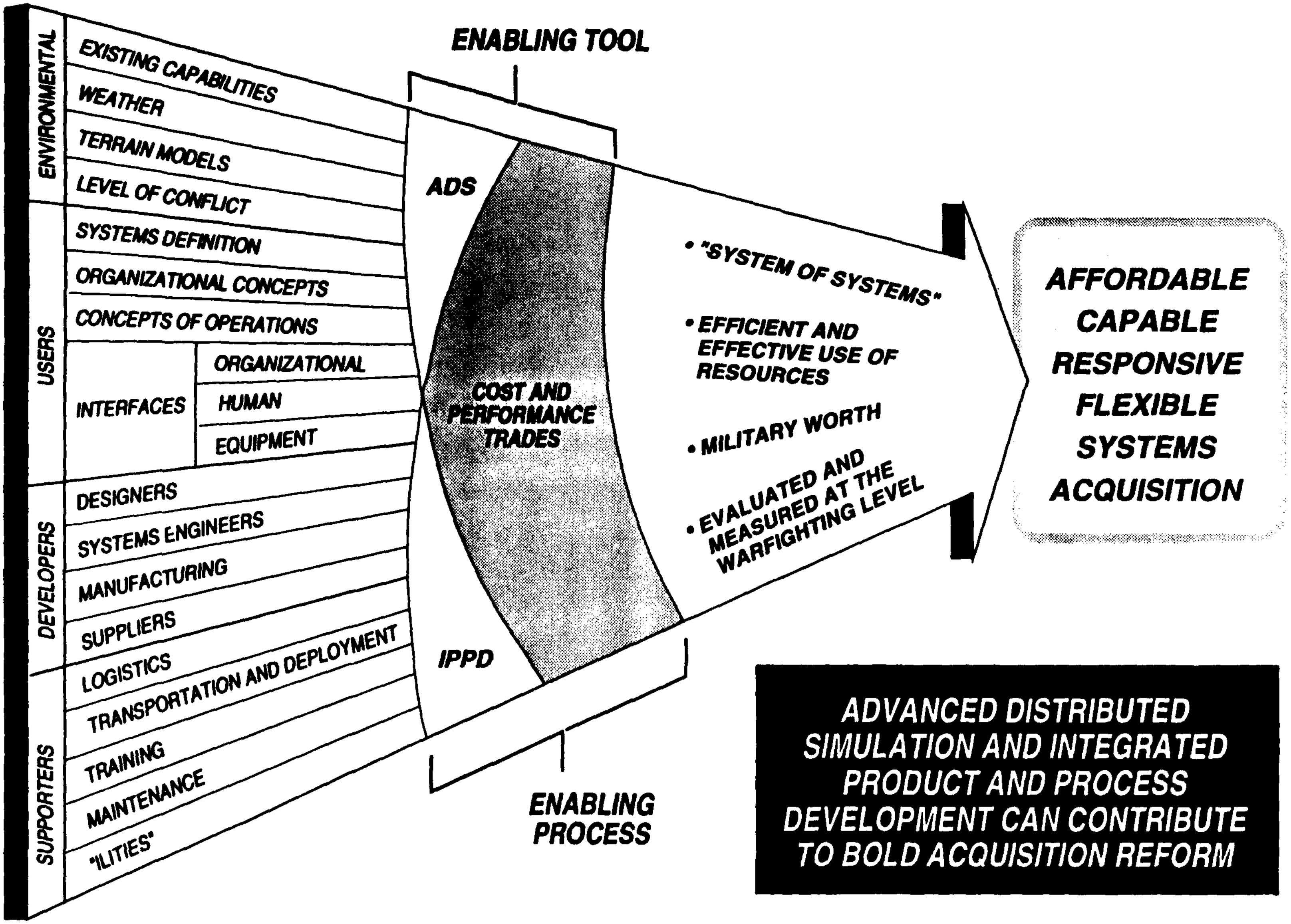
THE FUTURE



ADVANCED DISTRIBUTED SIMULATION AND INTEGRATED PRODUCT AND PROCESS DEVELOPMENT CAN CONTRIBUTE TO BOLD ACQUISITION REFORM

0283-93

II-D Information Technologies and the National Information Infrastructure

Dr. Duane A. Adams

ARPA

Information Technologies

Systems and Technology Symposium
Naval War College
Newport, Rhode Island

Duane A. Adams

22 June 1993

Information Technology

What is Information Technology?

What are some of the trends in Information Technology?

What kind of programs does ARPA have?

Information Technology at ARPA

SSTO
- Software Engineering
- Intelligent Systems

CSTO
- Computing Systems
-Networking

DSO
- Holographic Storage
- Algorithms

MTO
- Opto-electronics
- Neual Nets

ESTO
- Wireless
- Mobile
- Displays

ASTO
- Simulation
- Warbreaker

MSTO
- ASW
- Ship design

SPO
- HPC Applications

NMRO
- Seismic Center

<u>Across Offices:</u>
- Manufacturing (Design, Affordability, IPPD)
- National Information Infrastructure/Global Grid
- Advanced Technology Demonstrations

Information Technology at ARPA:

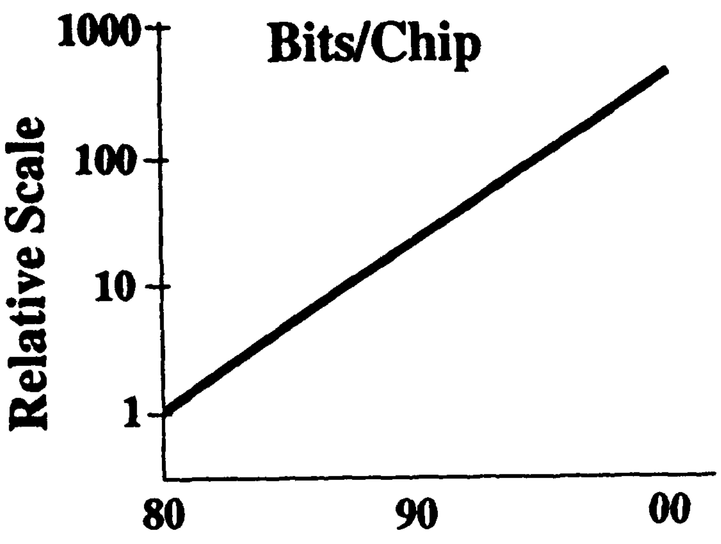
The ARPA emphasis on Information Technology is driven by several DoD needs:

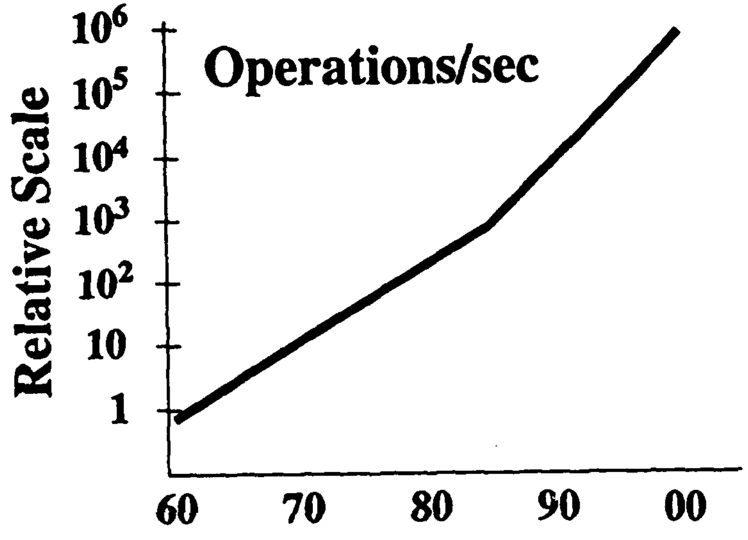
- **Affordability**—Simulation plays an important role in reducing costs in both training and in the acquisition of systems. Also, information technology plays an important role in the integration of product and process development activities.
- **Responsiveness**—Programs such as Warbreaker rely extensively in information technology to respond to time critical targets.
- **Reduced Manpower**—Information technology is being used to develop systems which require reduced manpower. Current programs at ARPA include those to reduce manpower needed to operate ships and satellite ground stations.
- **Shorter product development cycle**—Several opportunities exist for shortening the product development cycle, from the use of simulation to reduce the risks in manufacturing to using product-line software development technology to reduce the time to develop complex software systems.

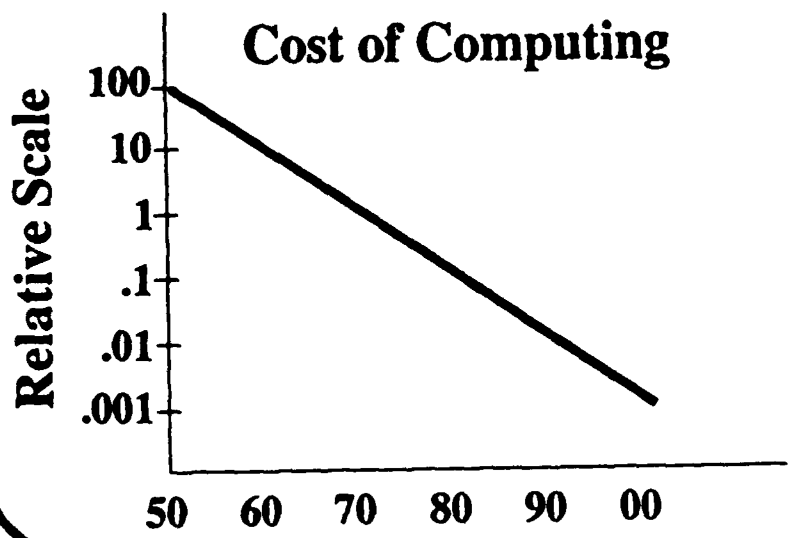
The same factors that are needed for Defense capabilities are also needed in the commercial sector, thus making information technology a truly dual-use technology.

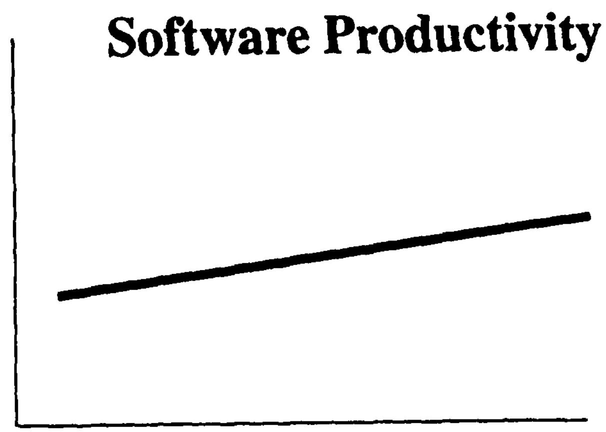
ARPA is also involved in programs that are just beginning to take shape, namely the National Information Infrastructure and the Global Grid, a DoD program to provide high performance networking and information services world-wide to meet DoD needs.

Technology Trends









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Technology Trends:

Three of the curves on this chart show that semiconductor and computer hardware continue to advance at an exponential rate, with the relative cost of computing benefiting from these trends.

- **Bits/Chip**—The number of bits/chip has been quadrupling every 3 years. The feature size is decreasing as well as the chip area increasing. (SIA Workshop, 1993)
- **Computing Systems**—The performance of computing systems has tracked the semiconductor performance. The bend in the curve in 1985 is attributed to be emergence of parallel systems. (CSTO data. Need a date and whether these are experimental systems or commercial. May want to check the work of Patterson and Hennessy)
- **Relative Cost of Computing**—The cost of computing has been halved approximately every 3 years. This is based on the cost per unit of computation for the most powerful commercial machines at any given time. (Scientific American, Sept. 1991)

Software Productivity—Software, on the other hand, presents a different story. It is first of all hard to decide which metrics are appropriate to describe the software improvements over time. Increased programmer productivity which is aided by language technology, software development tools and programming environments is one metric. Another is the extent to which reuse can be employed. This includes the reuse of system software, COTS systems, software components, and domain specific software architectures. For many DoD systems which will be in the field for 20 or more years, the ability to evolve the systems over time, the so called Post Deployment Software Support (PDSS) is a better measure of productivity, and this is strongly linked to the architecture of the system.

Other Trends

Convergence of computing and telecommunications
- Information Infrastructure

Development of applications jointly with the technologies

Ubiquitious computing; mobile computing

Open systems

Other Trends:

- **Convergence**—Distributed processing demands communications, as do client/server architectures. We have also seen the acceptance of ATM for use in local area networks as well as by the long-haul communication carriers. Communications are also essential for parallel systems, especially as we link workstations together over local area networks to create a loosely-connected multiprocessor system, and as we now begin to link supercomputer users together over gigabit networks. As the notion of an information infrastructure begins to emerge, we will see a wide range of computing services connected to networks, further blurring the distinction between computing and communications
- **Applications**—are now being developed in the context of an information infrastructure. The research in crisis management relies on database resources (intelligence, weather, order of battle) and computational resources (anchor desks) which are located elsewhere on a network and maintained by others. The notion of Agile Manufacturing will allow dynamic collaboration between companies in the conduct of manufacturing, including the creation of a virtual company that can be quickly assembled and disassembled when the job is completed. We are also beginning to relook at the provision of both health care and education in the context of an information infrastructure.
- **Ubiquitous computing**—As we develop computing systems which can be packaged in smaller spaces, require less power, and are powered with batteries having 5 to 10X greater energy density, we will have enabled a great deal of computing to be with the individual. This combined with greater use of wireless communications with make it possible to have access to computing from the home, office, car or any other place of business, and to be in contact with others from anywhere.
- **Open Systems**—By moving to an infrastructure in which a great number of resources are combined, there will be greater pressure to identify the areas of commonality so that systems can interoperate.

Challenges

Scaling
- computing systems
- communication systems

Software Development
- Acquisition of software intensive systems

Usability
- Access to information

Merging Defense and commercial needs
- NII and Global Grid

Rethinking applications to exploit information technology

Challenges:

While there has been enormous progress in developing computing and communication systems over the past decade, there are still major challenges ahead of us. The challenges are often at the system level rather than with developing individual technologies. Some of the challenges involve changing the way we do business, including changes to the acquisition systems and the associated cultural changes in both Government and industry.

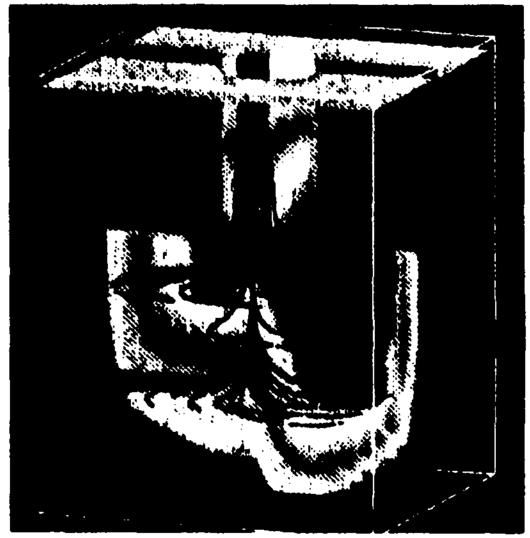
A challenge which pervades much of information technology is **scaling**. In the case of computing systems this means being able to gracefully scale a system to meet a user's needs, from a workstation to the highest performance systems. All components of the system must be scalable, including processing modules, interconnects, operating systems, compilers, and libraries. The challenge in communications is somewhat different: the challenge is to know how the system will respond as additional nodes are added to a network (a billion or more nodes) and as the bandwidth is increased (10 to 100 gigabits/second). In other words, are there limits beyond which the system cannot be extended, and what are they?

As a previous chart shows, **software development** technology has not kept pace with developments in hardware. We do not have good metrics to measure productivity, and the once-hoped-for solution from automatic programming, where a high-level set of specifications would be used to automatically generate a systems, has proved to be a very difficult problem. Current approaches focus on using processes which are based on using a domain-specific model with reuse across multiple applications in a product line. A particularly difficult problem will be to reform the acquisition process for software, and moving toward an evolutionary development approach in which the user and developer work very closely to evolve a system.

There is a trend to making information technology more widely available throughout society, from the individual soldier on the battlefield to information systems in our offices, homes and cars. In order for us to exploit the power of these systems, they must become **easier to use**, from being easier for the user to program to being able to find information on a network to being able to communicate with the system using human languages.

Many of the **applications** we wish to develop no longer operate on a single workstation or even on a single network; rather, they will exploit the information infrastructure which is evolving. To avoid the potential stovepiping of these applications, they need to be developed in the context of the infrastructure, and in fact, the applications and the infrastructure will evolve jointly.

High Performance Computing

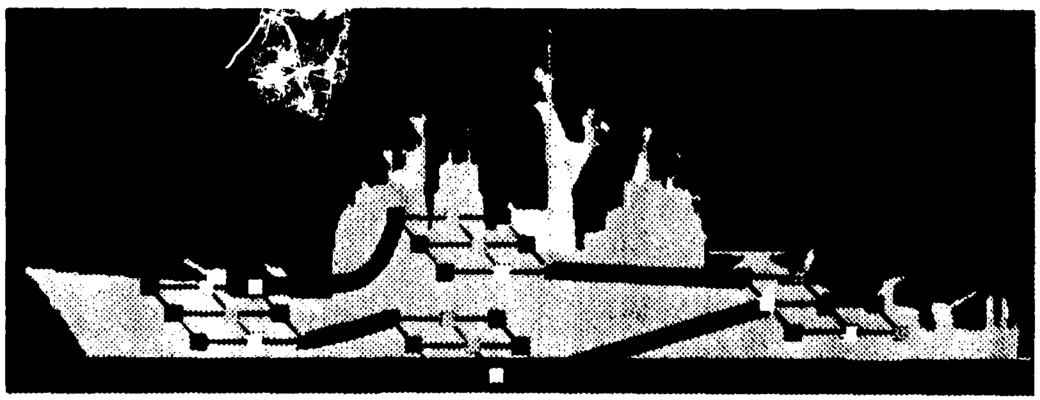


Scaling

System Software

Early Evaluations

Applications



Information Infrastructure

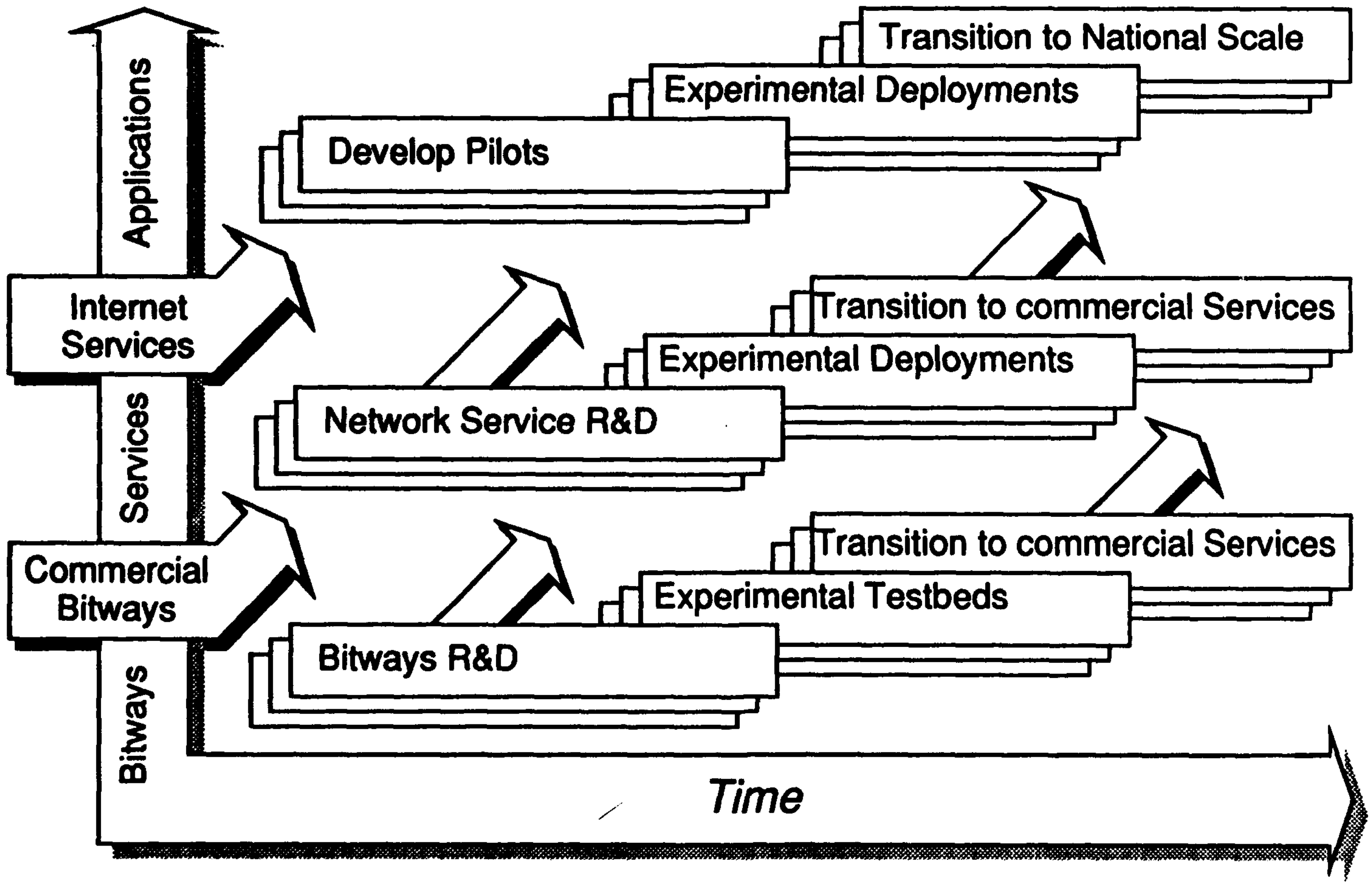
Applications (Examples)	Health Care	Education and Training	Design and Manuf	. . .	Crisis Mgtment
Services	Brokering Services Data Repositories Electronic Mail White/yellow pages		Framework Standards Security Protocols Mail Protocols Multi-media Protocols		
Bitways	Fiber Wireless Cable Satellite		Transport Protocols Transmission Standards Wireline/Wireless interfaces		

Information Infrastructure:

The concept of an *information infrastructure* has developed as more and more applications see the potential of using networks to advance their businesses in a cost-effective way. To some we have a form of an information infrastructure with the Internet today; to others the prospect of a high bandwidth set of bitways with shared, low-cost services opens vast new opportunities that we can only imagine today.

- bitways—integrate different modes of communication (fiber, wireless, cable, satellites). Not locked into a particular mode; need to accommodate all.
- In the service area some are more network oriented, others closer to applications. example of finding services vs. broker services that might only be good for manufacturing.
- Need to keep new ideas flowing into the infrastructure. A need for **diversity** and innovation. Examples in first column on Chart 7. Also a need for stability in the applications. This is commonality as examples are shown in the second column.
- The combinations of what is in the Services and Bitway blocks is called the information infrastructure.
- Both DoD and commercial. Talk about the Crisis Management example and the JTF ATD.

Information Infrastructure



Information Infrastructure II:

Chart 7 showed the components of an Information Infrastructure. Chart 8 portrays the evolution of the infrastructure over time.

- **Application pilot projects** can be developed using the internet services and commercial bitways that exist today. These pilot projects bring together the users, service providers and bitway providers into samll integrated teams, focused on developing applications which exploit the infrastructue.
- In parallel, **R&D** continues on the next generation of infrastructure technologies, often being demon strated in the context of R&D testbeds (examples are the gigabit testbeds).
- Successful pilot projects demonstrate a proof of principle, and provide both the technical and economic basis for expanding these capabilities to a **national scale**.
- Many information services may be common to several pilot projects or application domains. If we are to exploit the benefits of having a shared infrastructure, then it is necessary that services be common across different application domains, allowing for lower costs and shared information. The growing needs of applications will fuel the demand for bitways with greater capacity, more services, etc...
- The process of R&D, testbeds, pilot projects, national services, etc will continue.
- Support for high risk R&D, establishing pilot projects with diverse groups of participants, establishing appropriate standards, exploiting the information infrastructure for the benefit of the Federal government and insuring that an information infrastructure benefits all citizens are roles for the Government. Participating in these R&D and pilot projects, and creating a commercialy viable infrastructure are roles for the private sector.

Software Engineering

Goals:

- Close gap between user and developer
- Smooth transition from R&D thru acquisition and PDSS

Impact:

- Acquisition process
- Commercial products
- Education

Demonstrations

STARS, ATDs

↕

Experimental Integration

Evolutionary Software Development

↕

Focused Science

Language for software

High assurance software

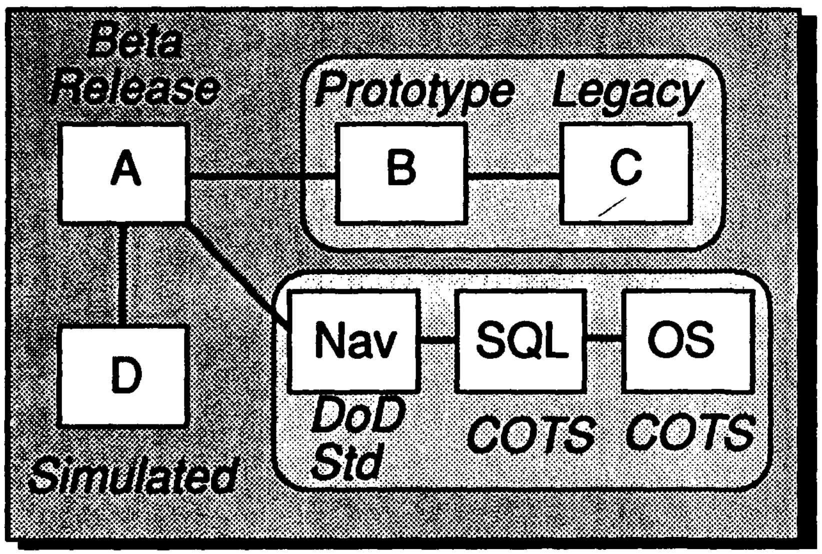
SOFTWARE DEVELOPMENT IS A CONTINUOUS PROCESS

Software Development 1:

Software has been estimated to cost the DoD nearly 10% of its budget, although adequate data is not available to confirm this estimate. Most major DoD software-intensive systems are still developed as custom software: as such they take too long to develop, are costly, and frequently fail to adequately meet the user's needs. The broad goals of the ARPa program in software engineering are to develop the necessary processes, tools and environments to enable a fundamental shift in the way we develop software. Such a shift will only be effective if there are corresponding changes in the way we acquire software. The main focus in the current program is to be able to develop software in an **evolutionary manner** which involves the user in the process, with frequent system updates and continuous system evaluation.

Software Engineering

Evolutionary Software Development



- **Process, Environments, and Tools**
- **Object Management**

Attributes

- **Architecture**
  - Anticipate Change
  - Seek Commonality
- **Heterogeneous**
  - Components from Diverse Sources
- **Evolve**
  - Add Functionality Incrementally
  - Components Evolve Individually
- **Early Validation**
  - Reduce Risk

Software Development 2:

Chart 10 gives more detail on what evolutionary software development is. Key concepts include:

- **Architecture**—The architecture of a system determines the extent to which a system can evolve over time. Research is now underway to develop a common architecture for given problem domains.
- **Reuse**—A key concept in improving productivity in developing systems is to employ reuse rather than to develop custom systems. There are many forms of reuse, from using a common architecture to create a product line of software systems for a given domain, to using common system software (such as operating systems) to using COTS software for functions such as database systems.
- **Early and continuous evaluation**—Early evaluation by the user is key to building systems which meet the user's needs. This is especially true for systems which are interactive, such as Command and Control systems. The goal in developing systems in an evolutionary manner is to make systems available to the user and to continually enhance these systems to meet changing user needs.
- **Tools and Environments**—Tools and environments must be developed to support the development process. The process and tools must evolve concurrently.

Intelligent Systems 1:

Autonomous Systems

- Note technologies which make it up

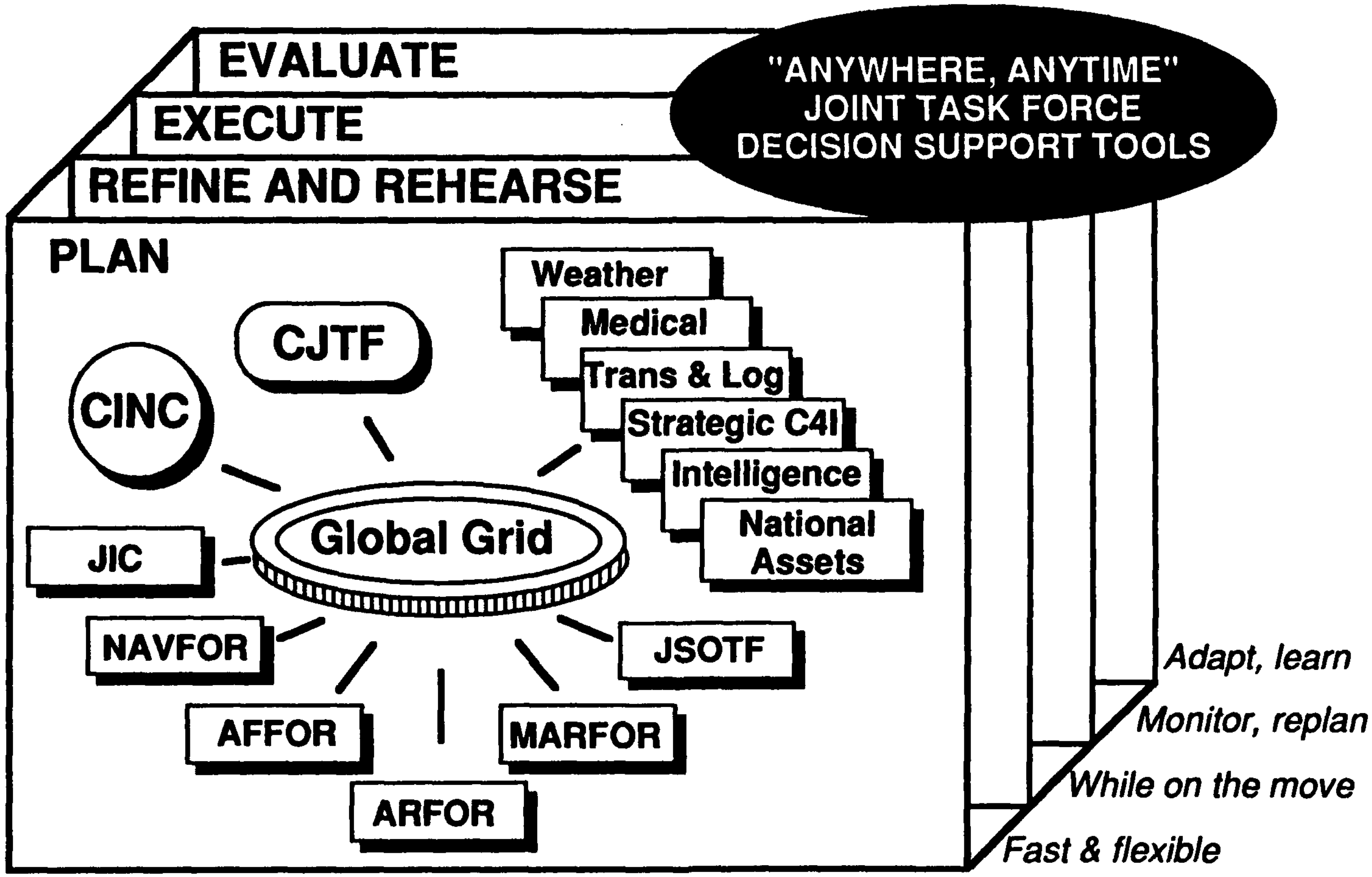
Advisory Systems

- Note technologies which make it up

Some themes:

- Integrating across the traditional areas of research (e.g. speech planning, problem solving, HCI)
- Focus on an application to give the research realism
- More concentration on the systems aspects of intelligent systems
- Application to several domains even if we are demonstrating in specific areas.

Intelligent Systems



Ubiquitous Computing:

Advances in display technology, packaging, wireless communications and the ability to interact with the computer with voice and gestures is paving the way to ubiquitous computing, that is, the availability to access computing and communication resources anyplace, anytime.

- **Mobility**—Small portable computing resources with wireless communictions will enable us to access our normal computing environments regardless where we are. New opportunities will be enabled, such as remote medical monitoring and notification and a variety of services that can be provided in the automobile. Technical challenges we are working on include integrating wireless communications into wireline communications in a seamless fashion, developing systems which can operate properly with periodic or intermittent connectivity, making more efficient use of the RF spectrum, and developing electronic packaging to meet the needs of mobile users (conformal electronics).
- **Displays**—One of the main enablers of ubiquitous computing has been the development of affordable flat panel displays. Laptop computers are widely available today. In the future displays will be embedded in helmets and in a variety of virtual reality devices. Integration of computing with the display
  - manufacturing issue
- **HCI**—
  - speech and other modes of communication
  - modeling user tasks
  - making systems easier to use

INFORMATION TECHNOLOGY SESSION III

CHAIR: DR. DUANE A. ADAMS

III-A HPC AND COMPUTING SYSTEMS

MR. STEPHEN L. SQUIRES

ARPA Symposium 1993

Extended Abstract
High Performance Computing Overview

Stephen L. Squires
Director
Computing Systems Technology Office

This extended abstract provides an overview of the ARPA HPC program in the context of the Federal HPCC program and introduces the next two talks on scalable computing and networking technologies.

Historical Timeline: High Performance Computing (HPC) technologies provide a fundamentally new kind of foundation for the information technology base of the 21st century. Developing and exploiting this new technology base provides new challenges and opportunities. The HPC technologies will be described in terms of their characteristics and trends which will enable a revolution in the application of information technologies in a new information infrastructure called an infostructure. The ARPA role in this revolution can be traced from ARPA's earliest investment in the 1960s in advanced computing up to current programs and plans for HPCC and its extension toward the NII.

Technology Trends: The rate of advance of computing technologies has been unprecedented in the history of technologies and is expected to continue. It current rate of advance has been fueled by the solid state switching device called the transistor which first emerged from research laboratories in the mid 1940s. Transistors are now produced at amazing rates through advanced manufacturing processes (see Scientific American Jun 93). Transistors are used to implement the designs of digital components for digital systems. The universality and economics of these systems have been and will continue to enable successive waves of innovation throughout all sectors of the technology base and its application throughout the society.

Converging Technologies: The universal nature of digital technologies and computation enable it to be used in diverse areas. Previously distinct information technologies have the potential of being combined in new ways when they are implemented with digital technologies with common interfaces. This enables the convergence of computing and communications technologies and their diverse applications into a powerful new *infostructure*. The fundamental power of the new technology base and its application is due to both computing available to its users and the communications among the computing systems and their users.

IT Advances and Applications over Time: History has shown the fundamental role that information has in the development of society and organizational structures. Fundamental change emerged advances such as the Guttenburg printing press, the telegraph and telephone, computing, time sharing, computer graphics, computer networks, VLSI, personal computing, scalable

computing, and their extension to mobile and wireless systems. Todays organizational structures are becoming increasingly dependent upon information technologies. These structures have evolved from a time before these technologies were dominated and are going through a reinvention process fueled by the new information technologies. This will provide new kinds of applications which we can only begin to imagine. In addition, the dynamic nature of the applications and the rate of advance of the technologies will continue to accelerate.

User View of Applications Development over Time: The combination of underlying technology trends and user trends presents challenges to insuring that rapidly advancing technology is able to meet the increasing dynamic of the users. Meeting this challenge will require a much more integrated view of the technologies and their users. In the past the gap between users and technology has been filled by system developers. While this may have worked in the past, it is not going to be capable of working in the future because it will not be able to keep pace with the dynamics of the user environment. Technology has an impact on their users who develop new concepts as a result of their experience using it. Users want increasing control over the systems they use so that the systems will continue to keep pace with their understanding of what they learn they need through their use.

System Architecture for Sustained Graceful Growth: The new computing technology base needs to be able to support sustained graceful growth from both the user and technology perspective. From a user perspective the systems need to be able to grow in capability as users grow from their experience in their use. From a technology perspective the underlying systems need to be able to have functions and components inserted as the technology continues to advance. Both of these perspectives need to be able to progress at their own rates while providing feedback to each to sustain the rate of mutual advance. Accomplishing this will require an overall system architecture to break the mutual dependencies.

Inventing the Future through Advanced Prototyping: The elements of the new approaches required are emerging from todays research laboratories as they pursue innovative projects focused toward inventing the future. This is accomplished by using the best of todays advanced technologies in innovative ways that represent the way in which those technologies are expected to be used in the future. These innovation laboratories are connected the Internet which is a prototype of the infostructure. Computing is fundamental and pervasive in these laboratories provides a window into the future. Examples using this approach will be given from previous ARPA programs in advanced computing technologies.

Major Dimensions of the New Computing Technologies: The major dimensions of the new technology base are characterized by scalable, ubiquitous, universal, affordable, open, integrated and reflexive while providing privacy, security, integrity, and trust. Each of these dimensions will be described to provide insight into the structure of the new technology base. Scalable means that a single design can be configured over a wide performance range. This enables the system performance to be matched to the user need. Ubiquitous means that it can be placed wherever it is needed. This enables systems to be virtualized to their IT based models providing improved observability and controllability. Universal means that the needed functionality an be achieved from a common foundation within the limits of computability and approximations. Affordable means that this becomes the preferred solution in economic terms and is enabled by the

continuing advance of the technology. Open enables different system modules to be composed as needed to achieve the desired overall systems capability. This enables the reuse of modules in various forms. Integrated means that the overall system of modules works together as if it were developed as an integrated whole. This provides a uniform appearance to the user. Reflexive means that the system modules include descriptions of itself which enable more effective composition of systems from modules since they have an integrated systems configuration capability.

Dual Use Technologies: Notice that all of these concepts apply to both commercial and defense systems. This is an example of what we mean by dual use technologies. In almost all cases, high performance computing is a dual use technology base that enables the full range of information technologies including their extension to an infostructure.

The next two talk will go into more detail for high performance computing and high performance networking technologies.

High Performance Computing Overview

Stephen L. Squires
Director

History, Current, Futures

From SC, to HPC, toward NIE

As Foundations for HPCC, toward NII, and beyond

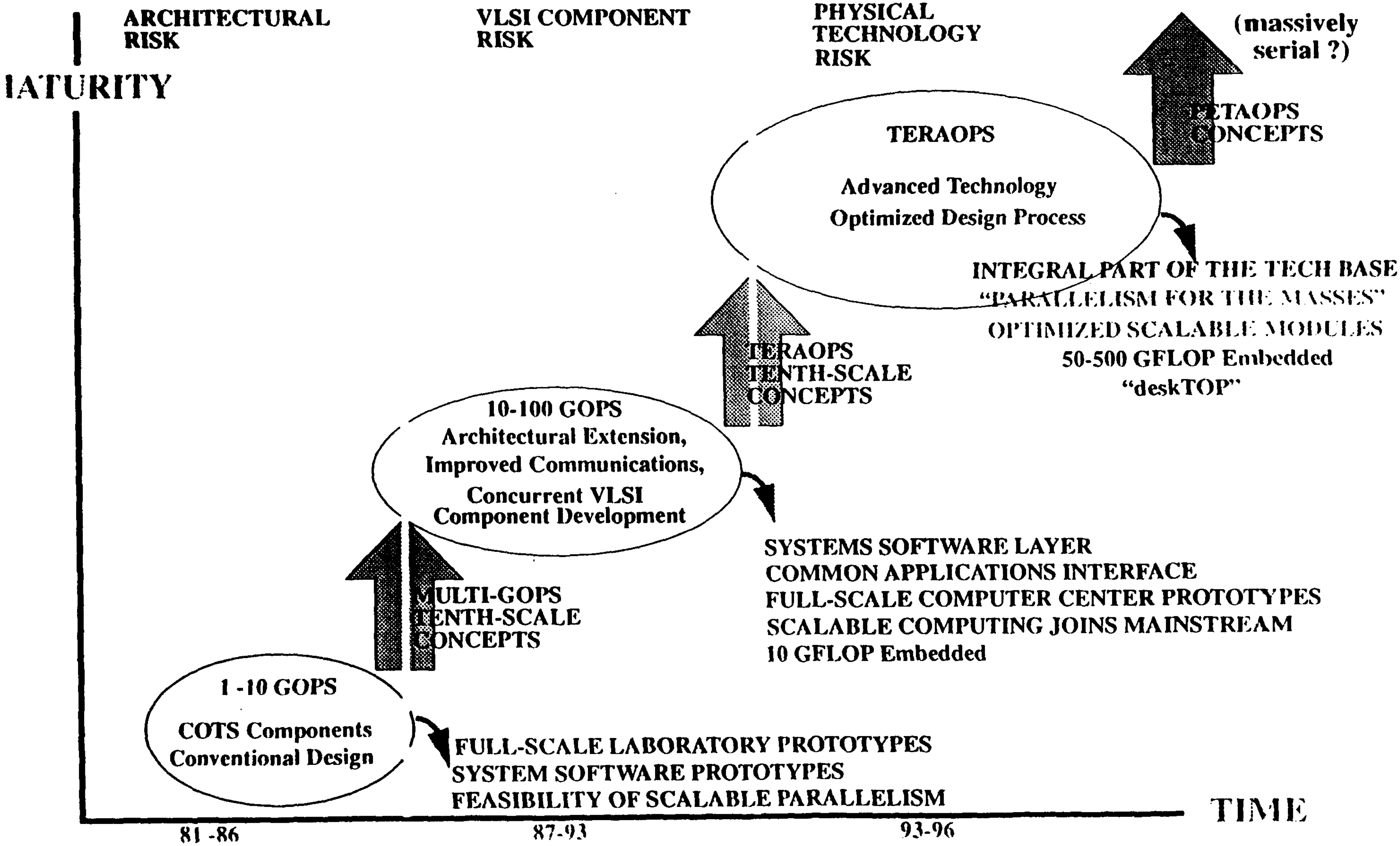
From Serial

to Scalable and Massively Parallel

to Parallel for the Masses

to Universal and Ubiquitous

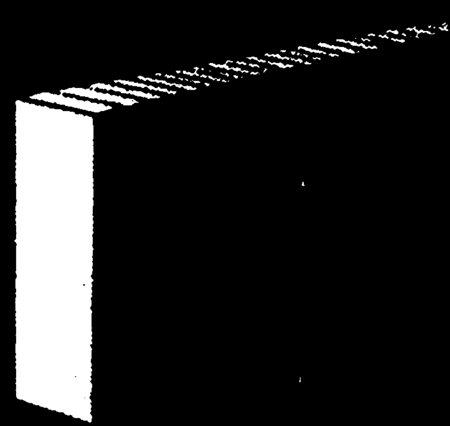
THE EVOLUTION OF HPC



Scalable Systems Projects

- Intel Paragon
- TMC CM-5
- CRI T3D
- Tera
- MIT/Motorola *T
- CalTech - Mosaic
- MIT - M Machine
- Others ...

Intel Paragon

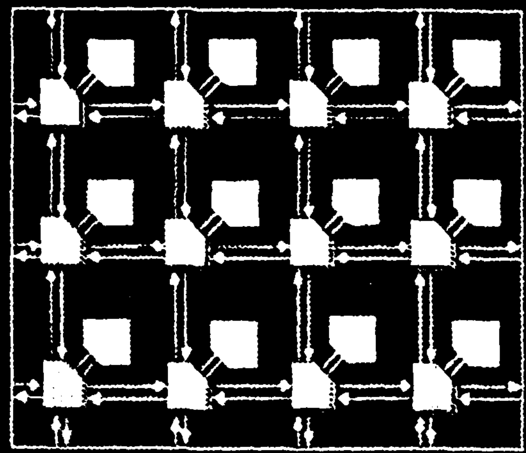


A family of scalable systems from 5 GFLOPS to 300 GFLOPS

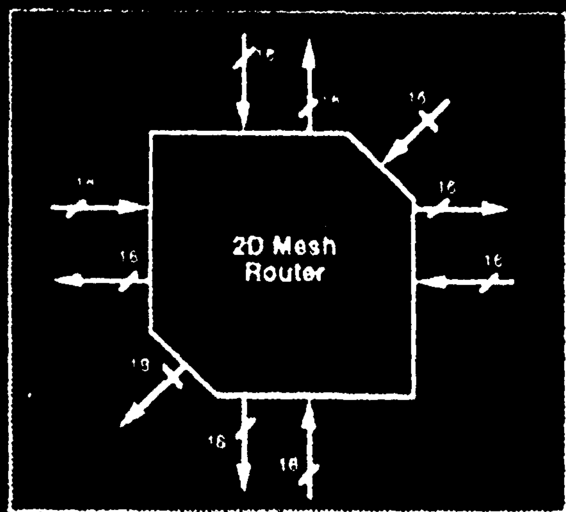
- Scalable integer performance to 160K MIPS
- Scalable main memory to 128 Gbytes
- Scalable internal disk storage to a Terabyte
- Scalable external connections to 6.4 GB/sec

Scalable Interconnection Network

- **System-Wide Communication Fabric**
  - handles all inter-node communication
  - handles all I/O communication
- **Physically Independent 2D Mesh Design**
  - arbitrary expansion increments
  - node fault isolation
- **"Flat" Performance Characteristics**
  - 200 MB/s between any two nodes (full duplex)
  - less 5% latency variance across network
- **Enormous Bandwidth Reserves**
  - scales with network size
  - over 12.8 GB/s bisection B/W (32x32)



Scalable Interconnect Technology

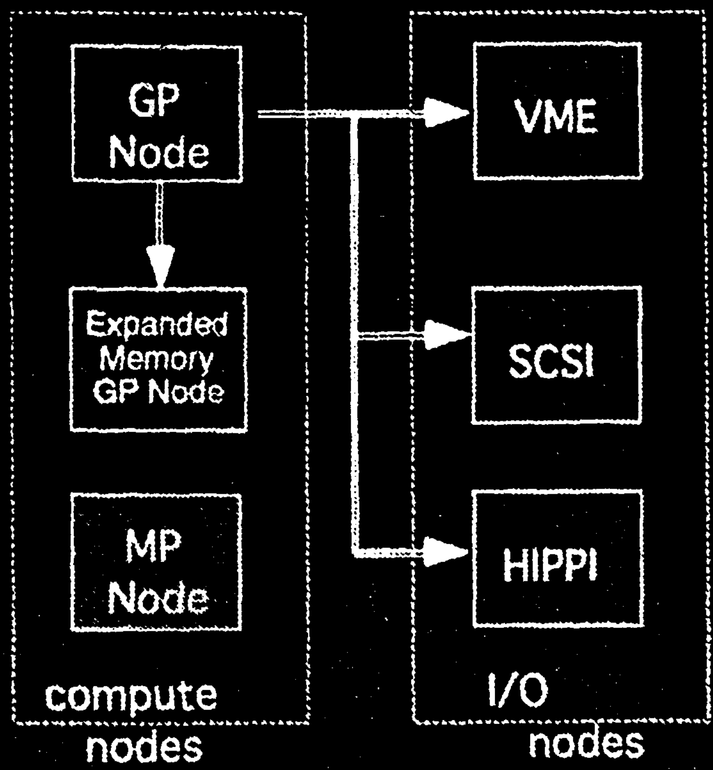


- Single 325-pin VLSI chip
- 16-bit channels:
  - 200 MBytes/s each
  - full duplex
  - wire-pipelined
- Wormhole routing
- Sub-mesh broadcast
- 40 nsec input to input latency
- Self-timed and parity checked

Based on Intel's fastest commercial VLSI process technology

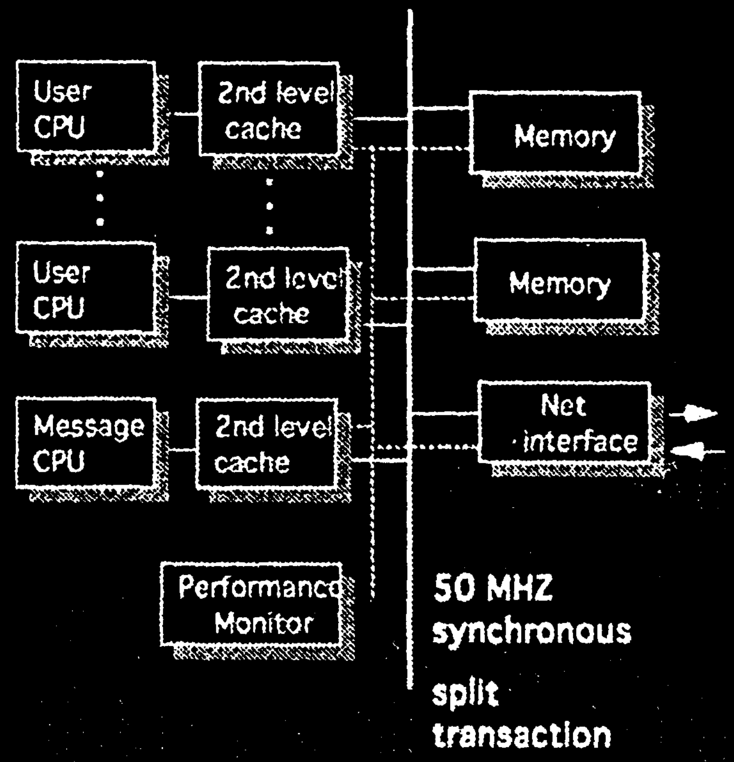
Flexible Processing Elements

- **General Purpose Node**
  - compute, service, or I/O
  - expandable memory
  - SCSI, HIPPI, or VME interfaces
- **Multiprocessor Node**
  - compute or service
  - highest computational density

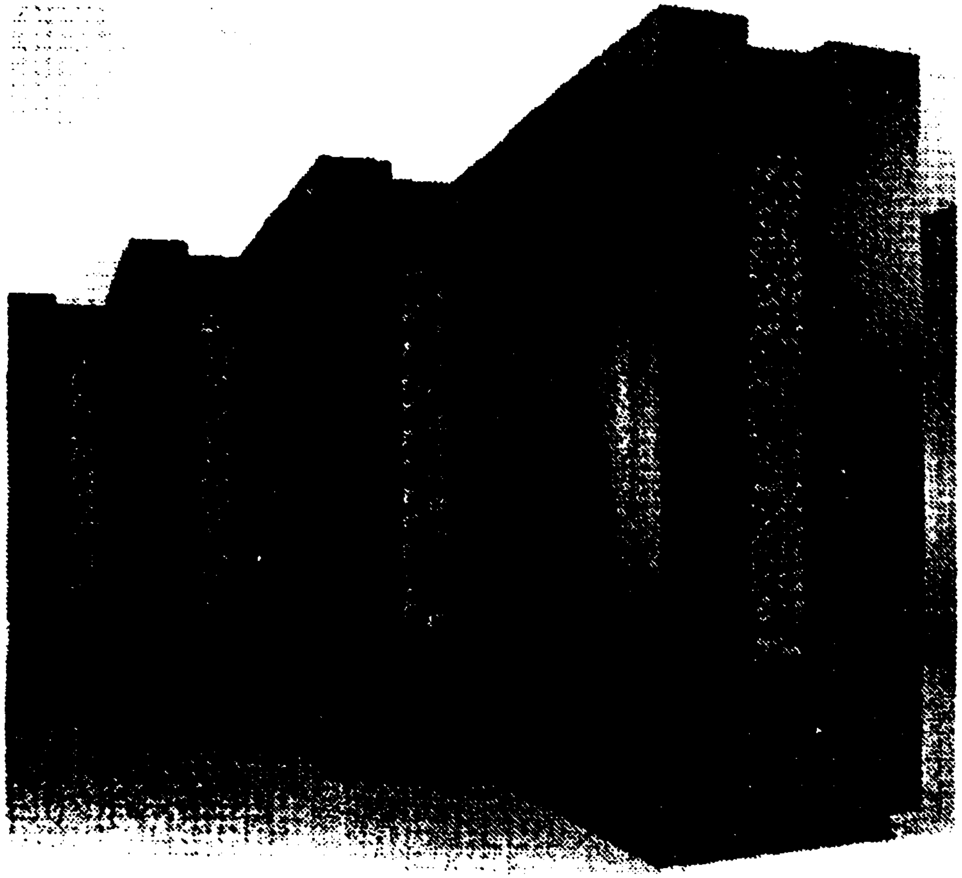


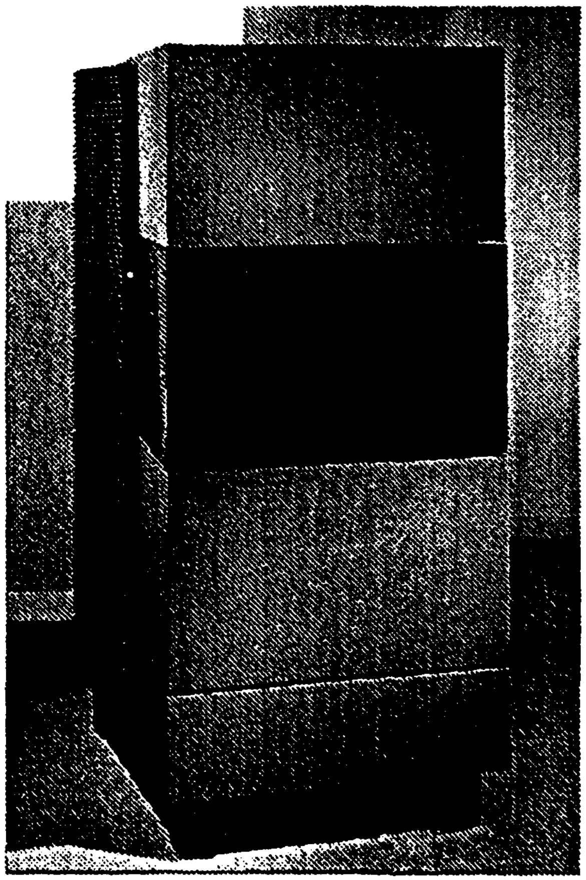
Powerful MP Node

- Locally Shared Memory
  - four i860XP user CPUs
  - fully symmetric design
- High Density Packaging
  - 300 MFLOPS/160 MIPS
- Interleaved Memory
- Optimized Messaging H/W
- Performance Monitor



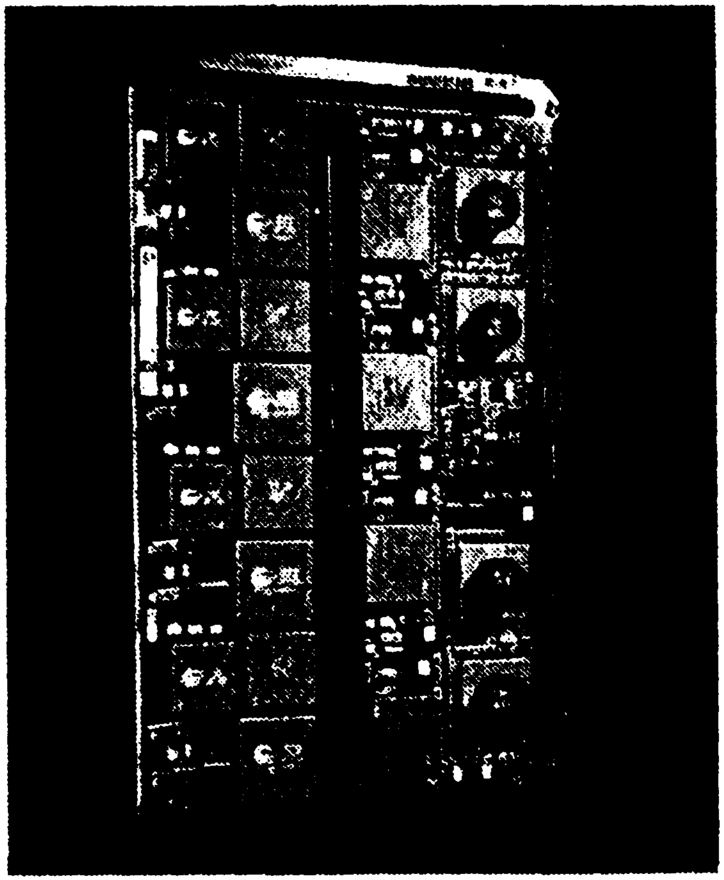
TMC-CM5



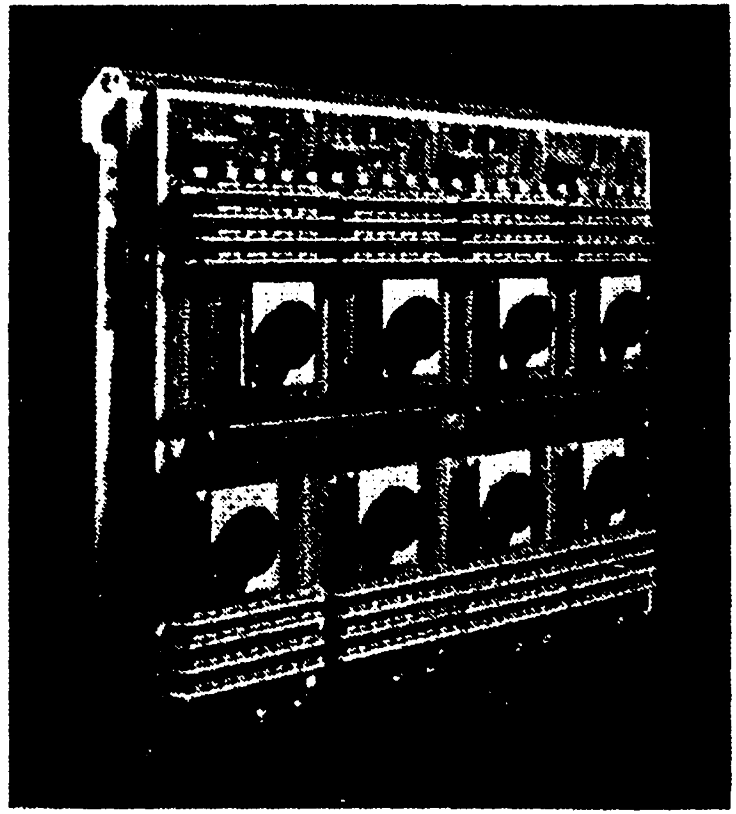


TMC-CM5

Processing Element Board

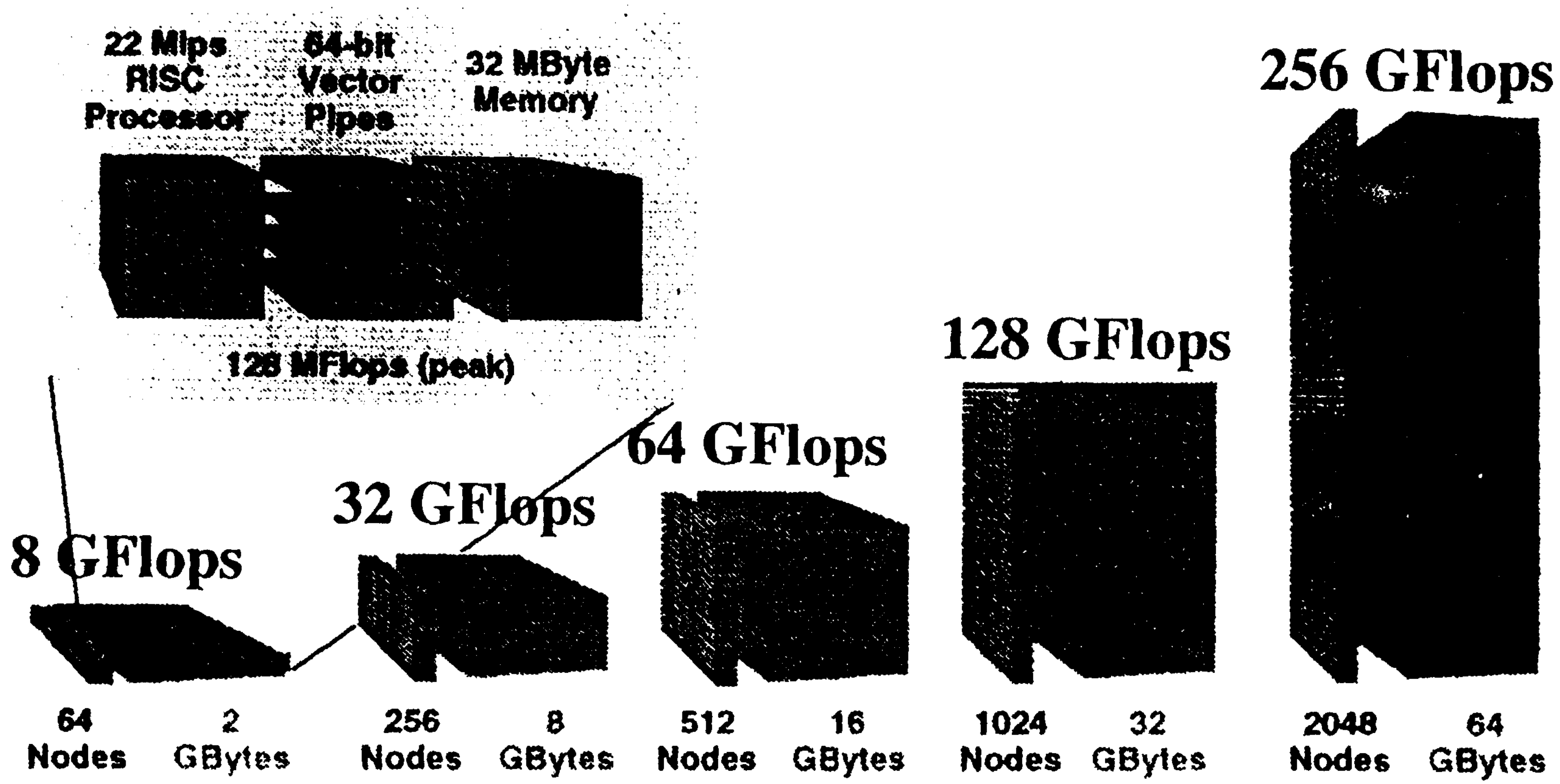


Vector Unit Memory Board

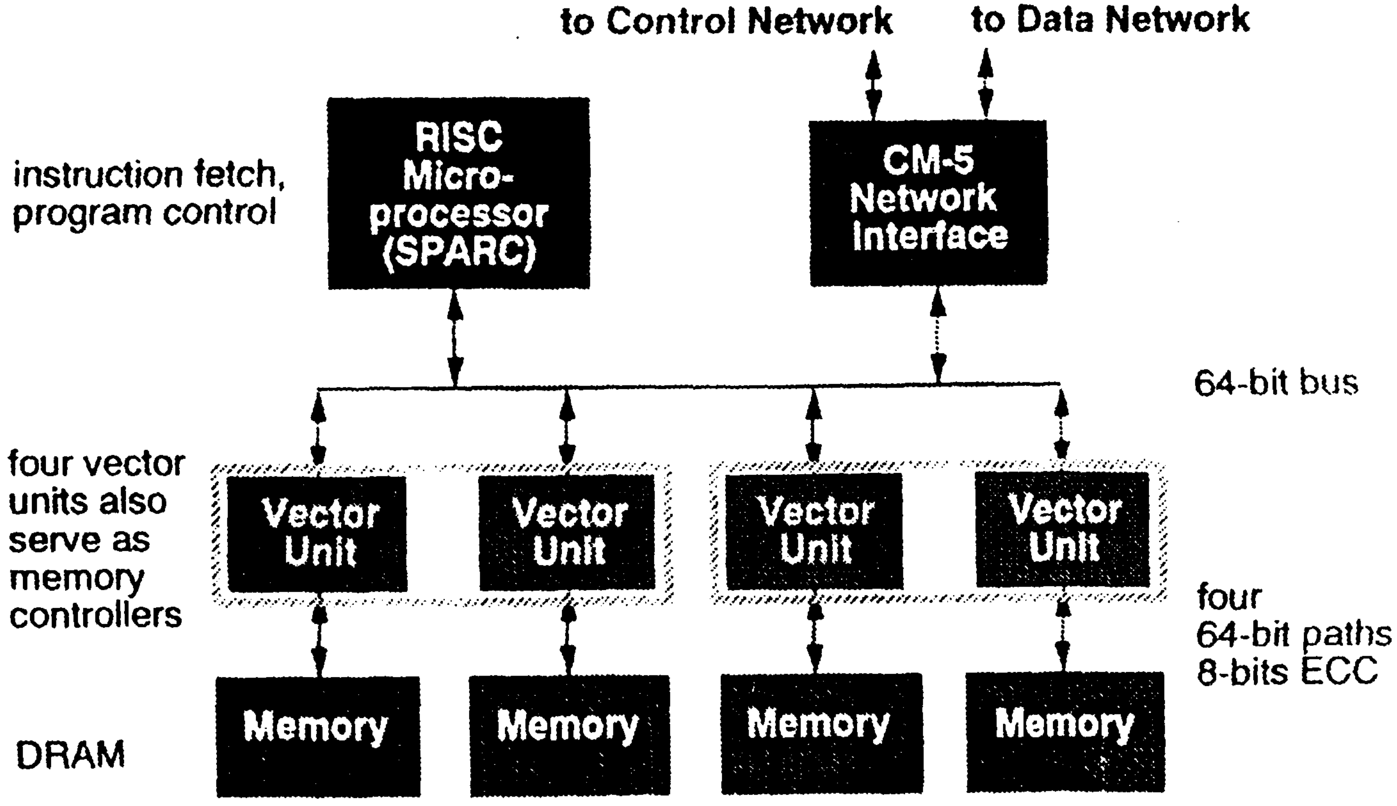


Board dimensions: 11 x 17 in^2

Scalable CM-5 Processing

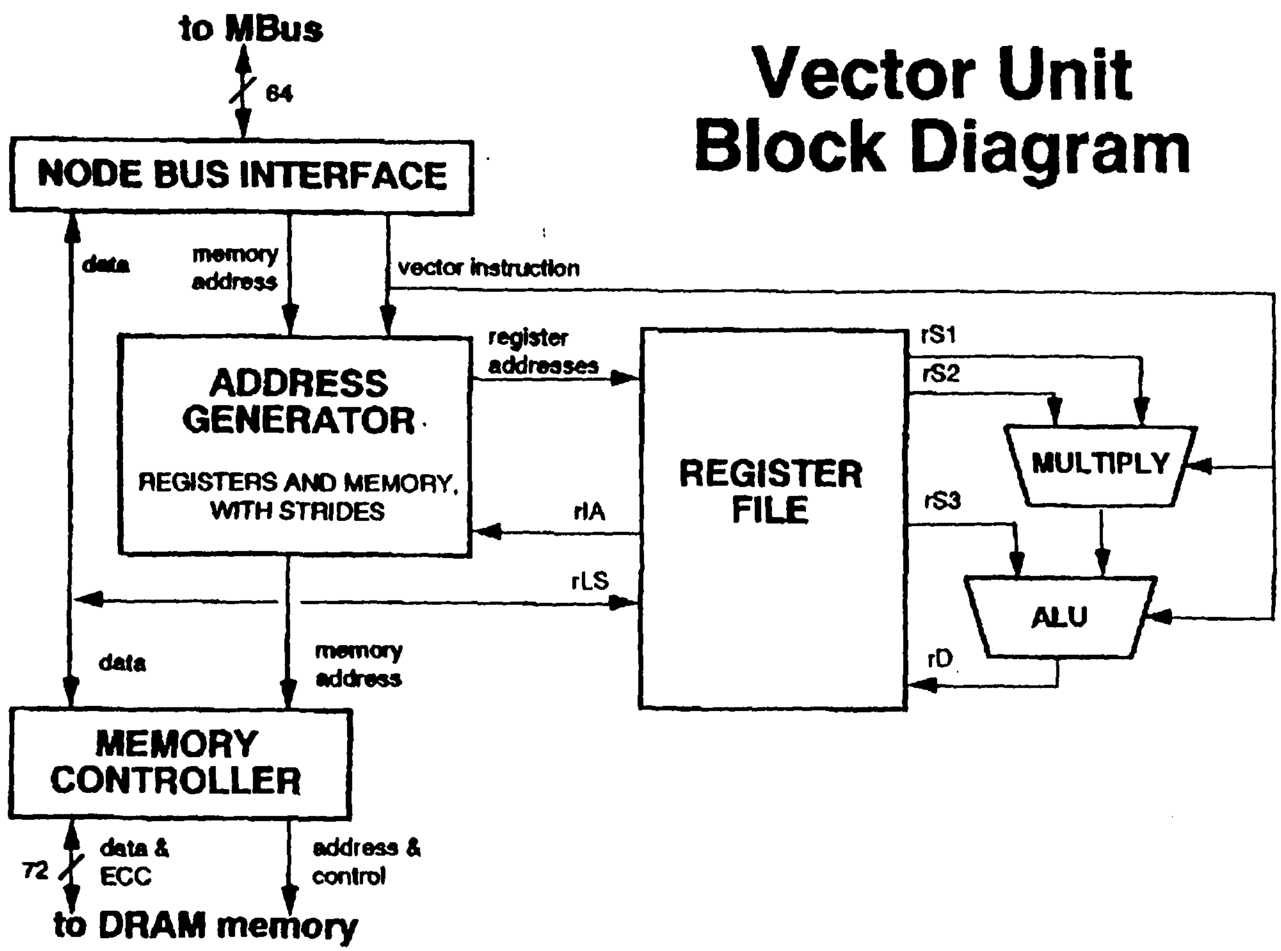


CM-5 Processing Node with Vector Units

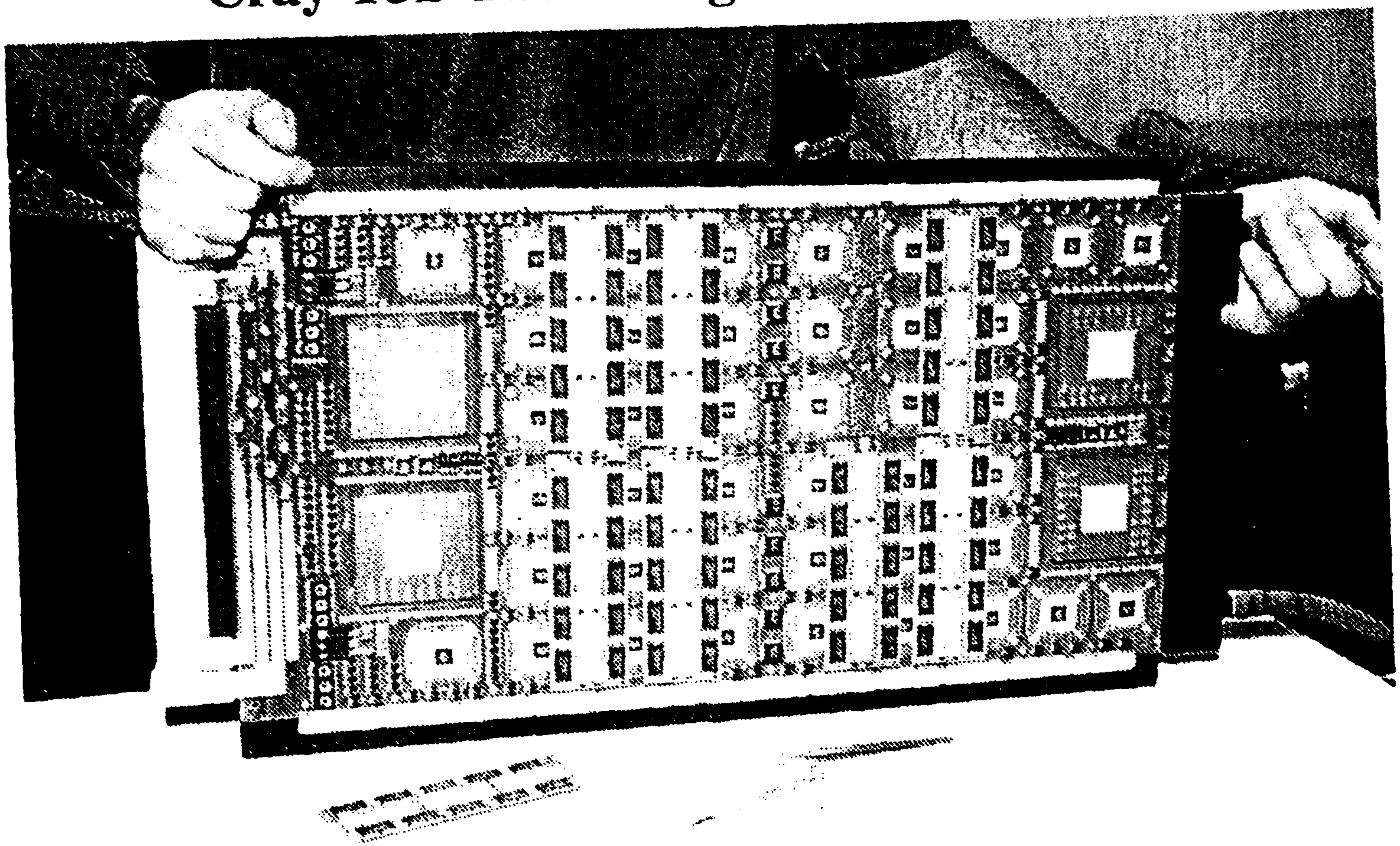


TMC-CM5

Vector Unit Block Diagram



Cray T3D Processing Element Module



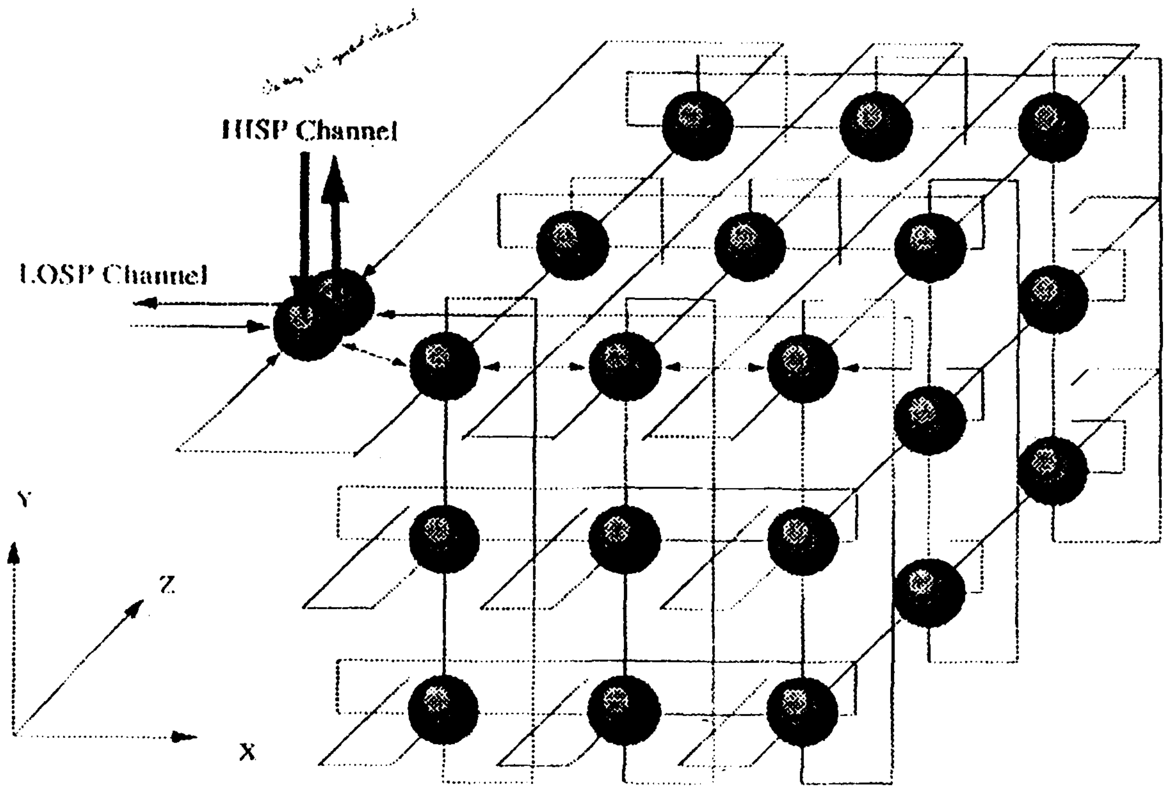
Cray T3D Macro Architecture

Physically distributed memory
Logically shared memory
3-D torus interconnect network
Fast barrier synchronization capability
Fast memory locks
Support for dynamic loop distribution
Messaging capability
Block transfer engine
Local cache memory

Cray T3D

Network Topology

3-D Torus with I/O nodes

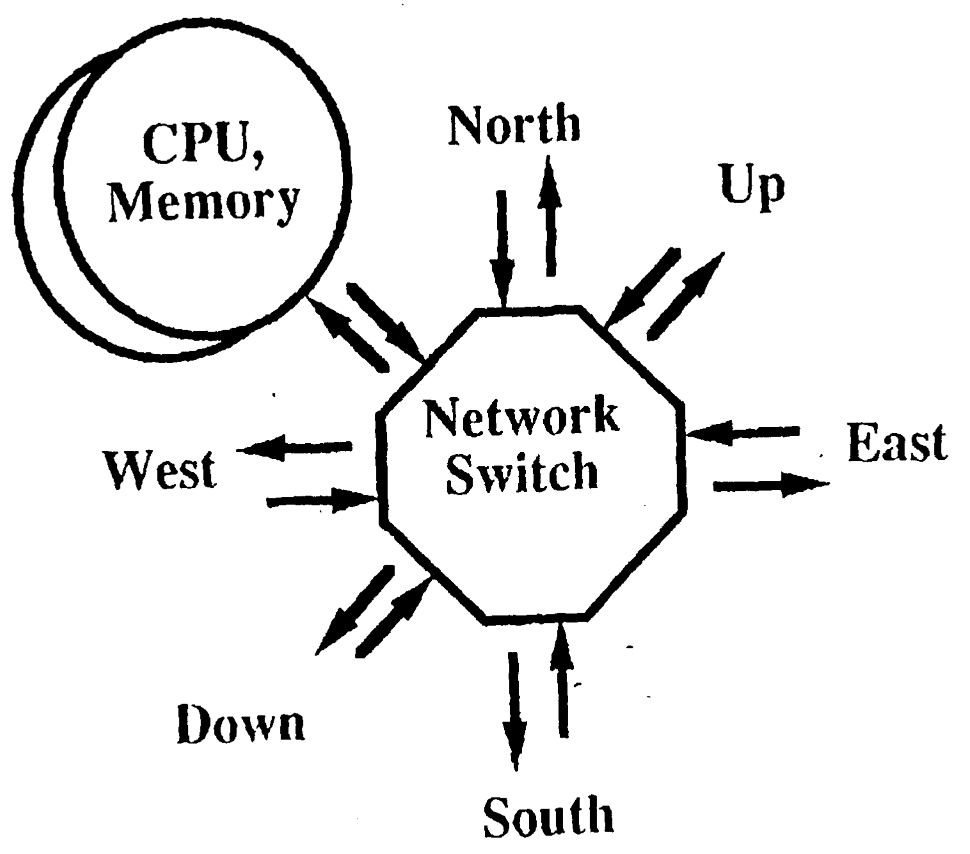


Cray T3D

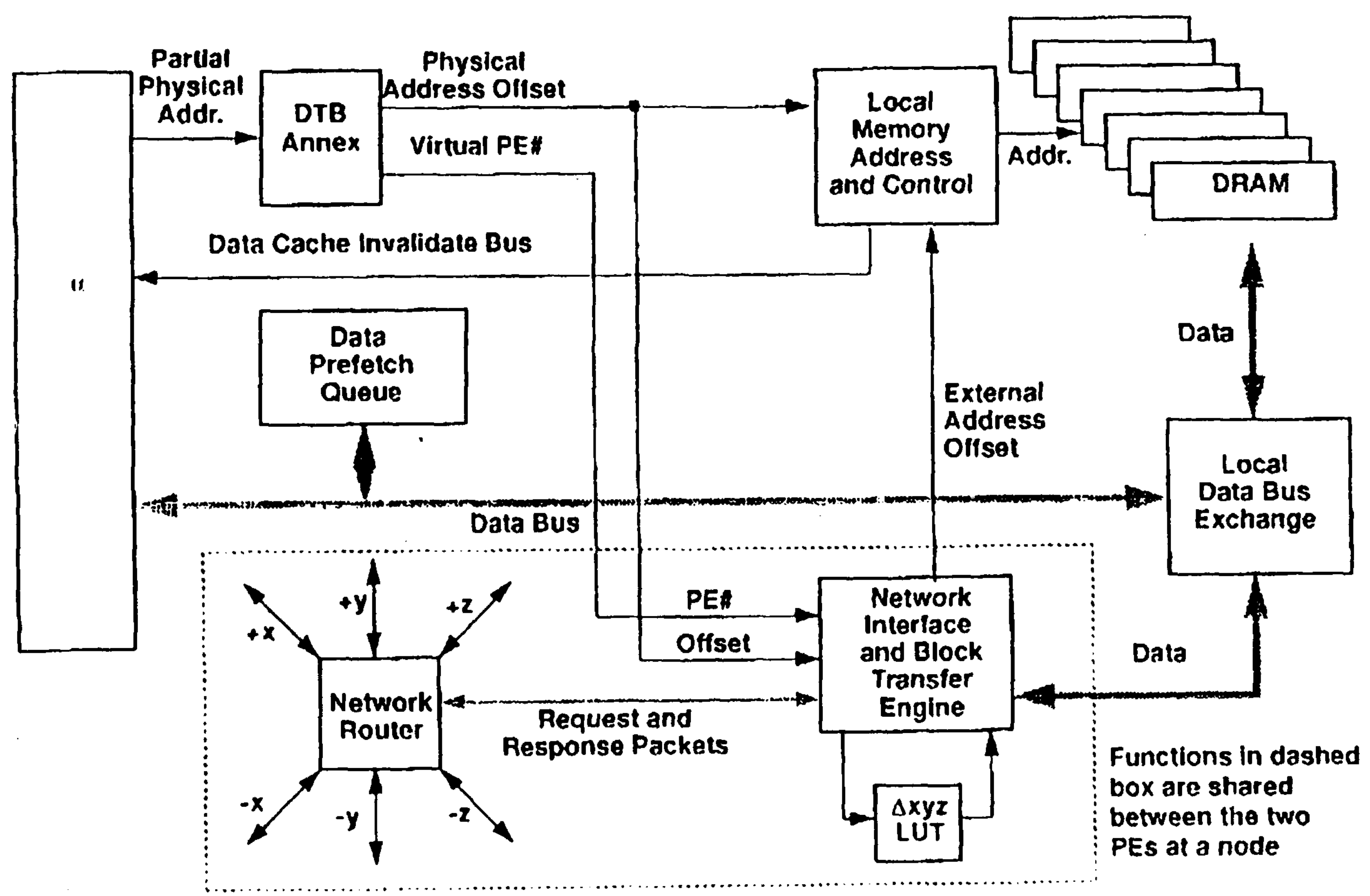
DEC Alpha Microprocessor
- CMOS, 150 MHZ clock
- 150 MFlops (64 bit precision)
- 64 bit registers (32 integer, 32 floating-point)

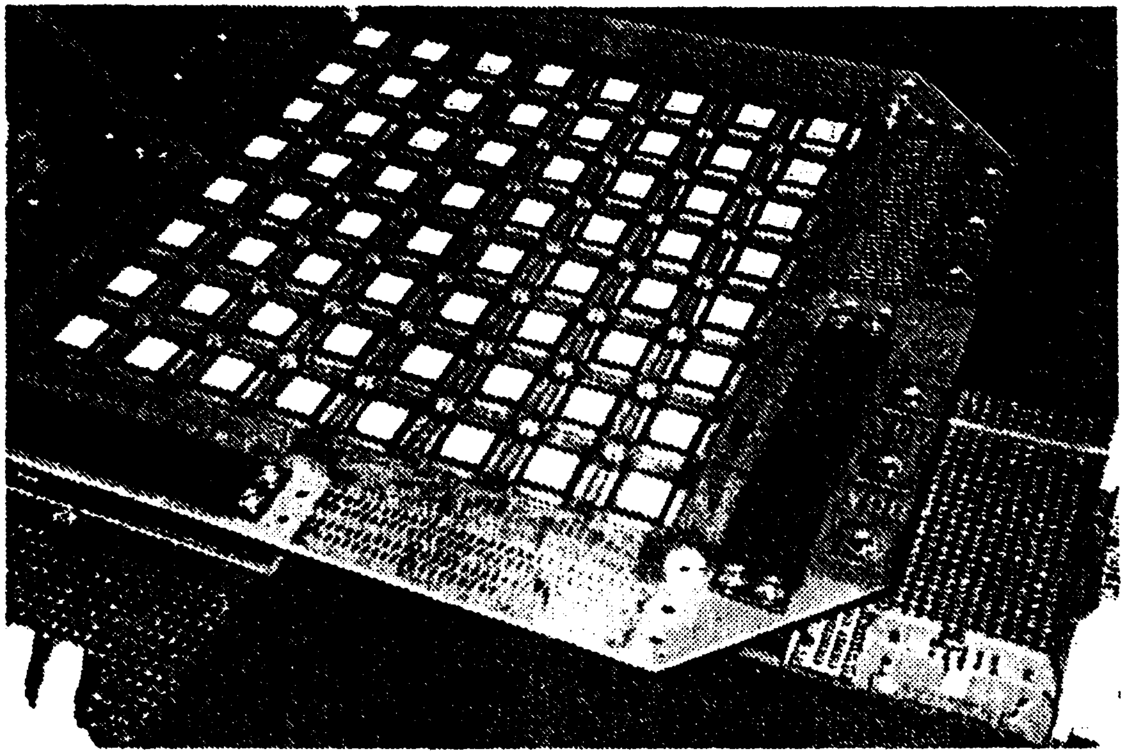
Communication Data Paths
- 300 MB/sec each direction
- 16 bits wide @ 150MHZ

Cray T3D Processing Element Node



Cray T3D Processing Element Organization





Caltech Mosaic C - - 64 processor computational plane;
16 megabytes, 125 watts, 3 Gips, 60 Mbytes/sec 2-D routers

Computing

- The full system context
  - from user to computing and infostructure
- including hardware modules
  - networking
  - input/output (including real world)
  - mass storage
  - archival storage
  - displays
- including software modules
  - operating system and services
  - libraries
  - programming languages
  - system development and support environments

User Access to server model and beyond...

New kinds of projects

- The joint ARPA/NSF (and ARPA/Other) model
- The NCHPC model
- Early Evaluation and Experimental Use
- Completing the technology base
- Focus on enabling technologies for the user
- Optimal Units of Replication for Future Generations
- Technology Foundations for Future Generations
- Extension to enable IITA

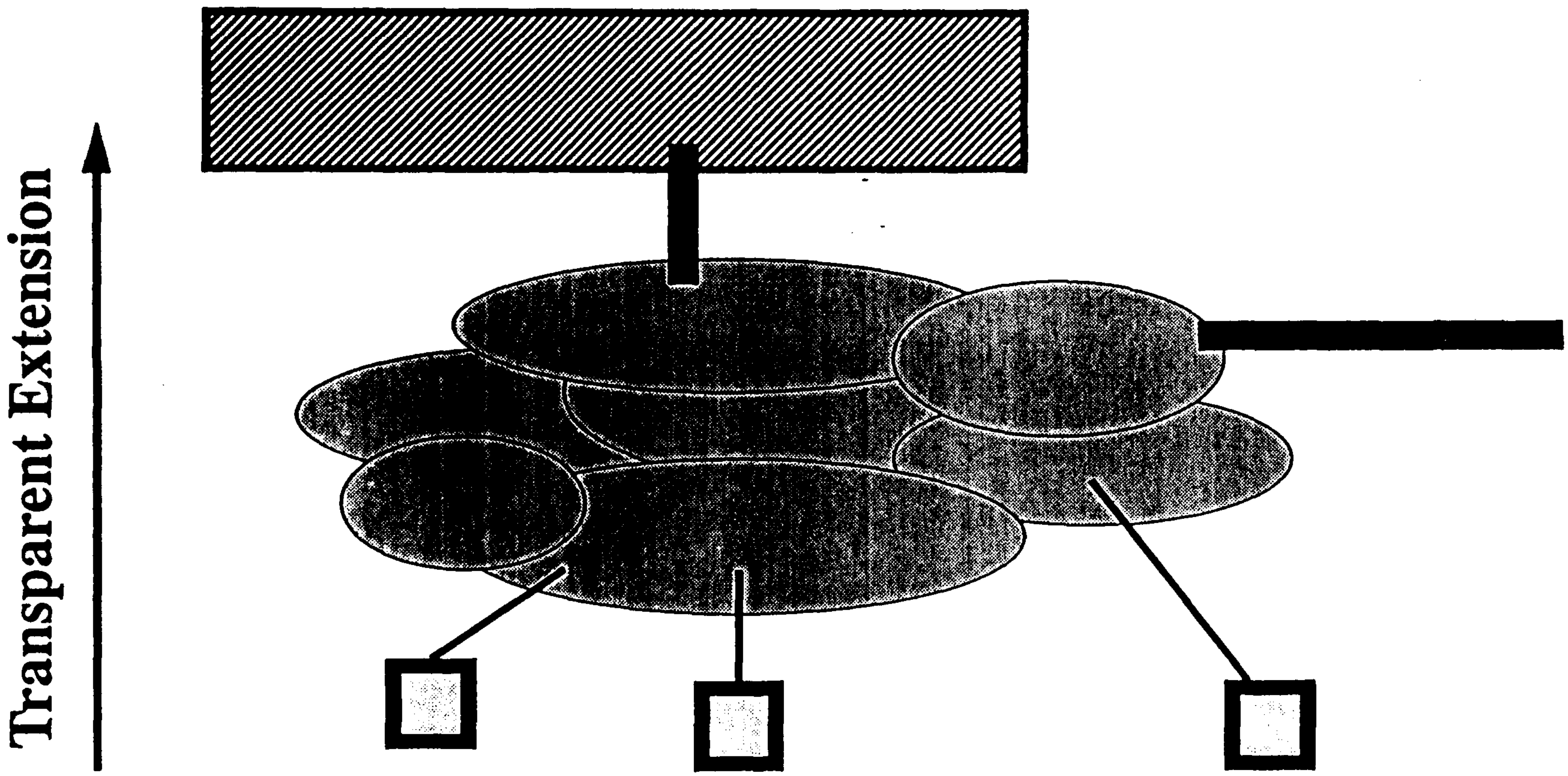
Common API

within a family from workstation to server

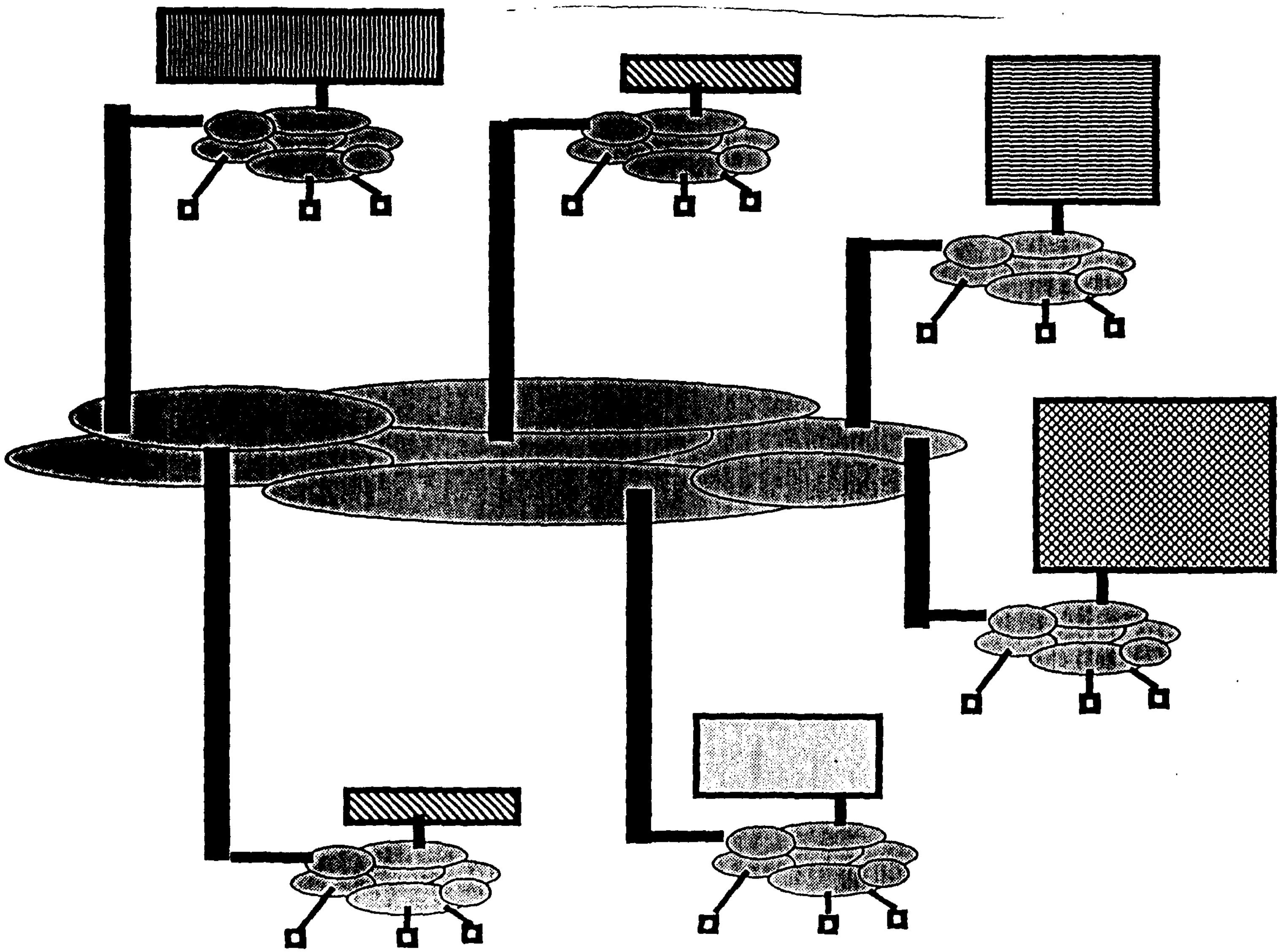
across different families

Enables scalable software over broad range of systems and configurations.

Workstation Server System



Hetergeneous Systems

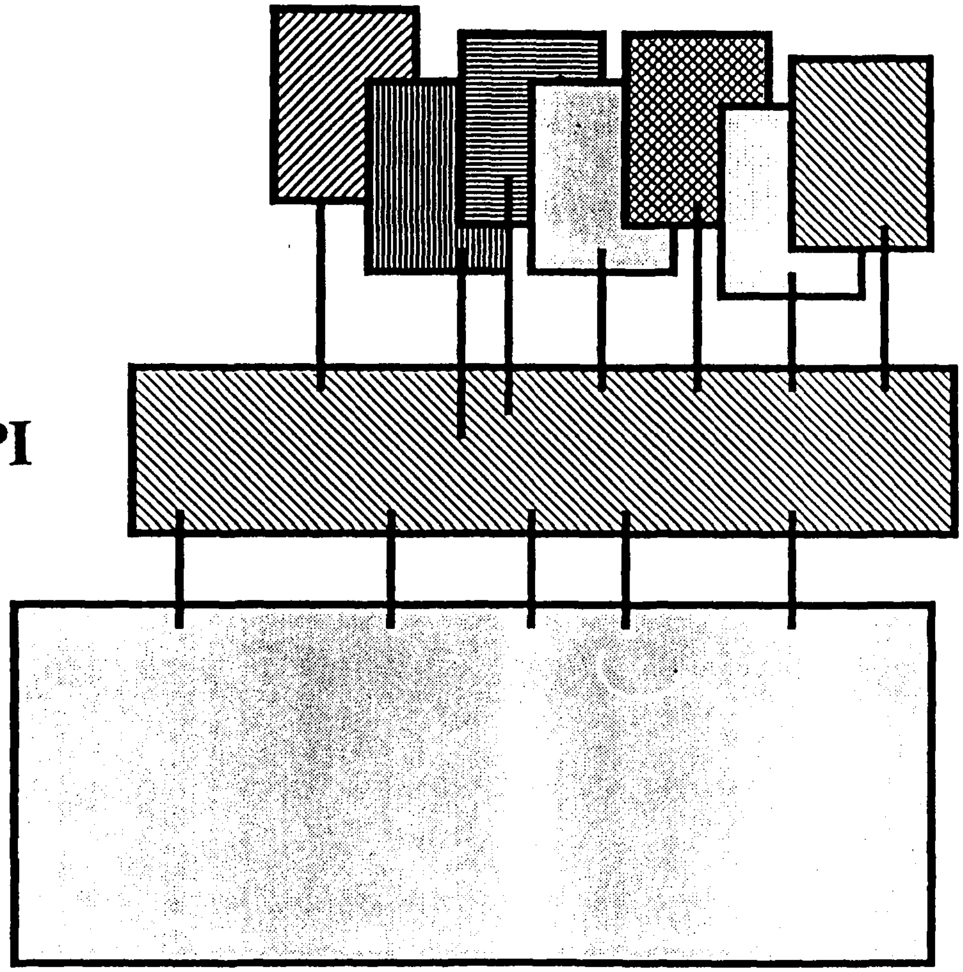


Towards a Common Applications Programming Interface

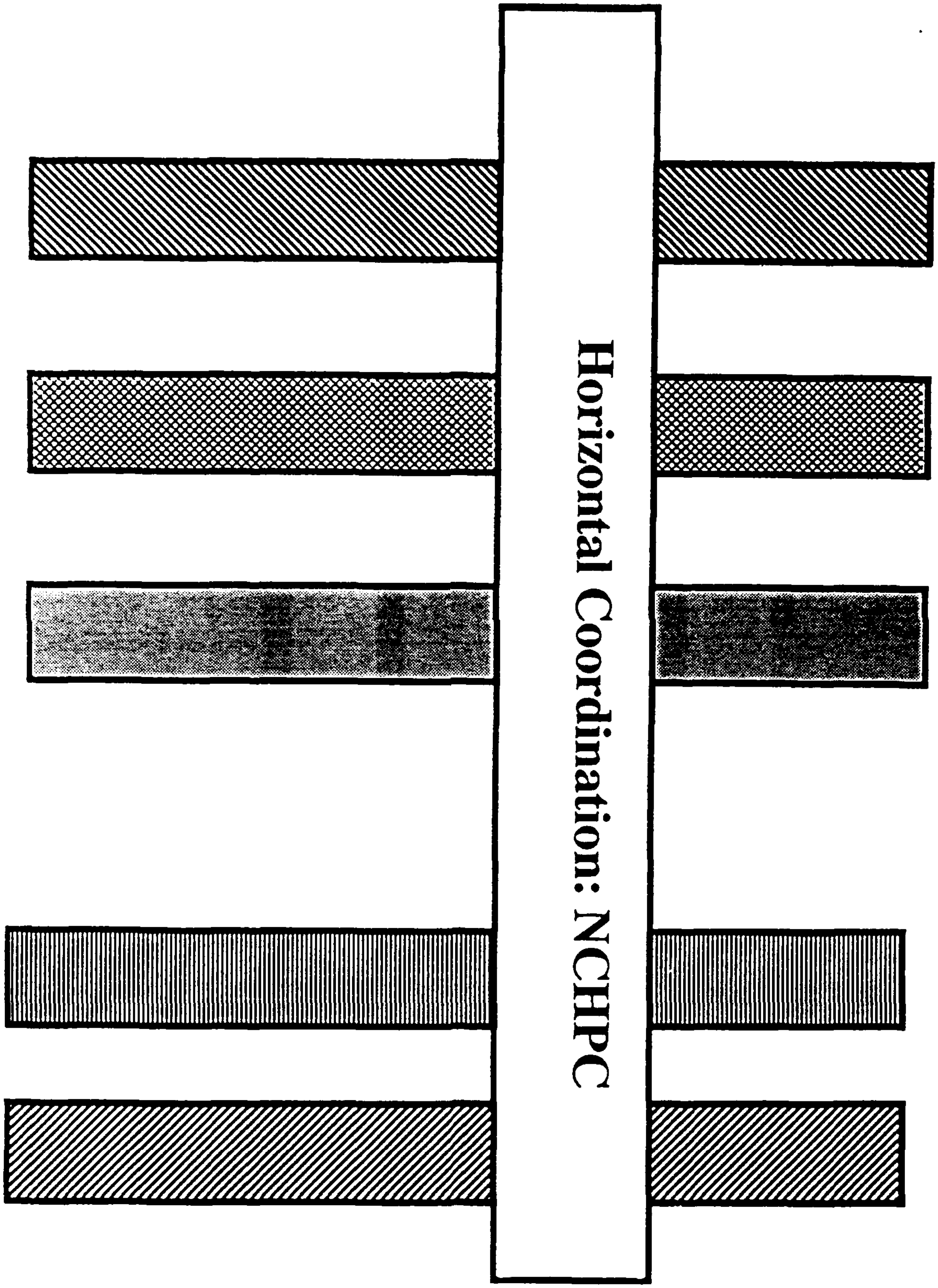
Applications

Common API

Facilities



Vertical Coordination: Joint ARPA/Others



Early Evaluation and Experimental Use

- Small systems for early software development and initial evaluation
- Medium systems for scaling experiments and resources sharing developments
- Joint with other sites with greatest expertise and potential
- Limited to a limited number of medium size equivalents
- Scale up through other mechanisms

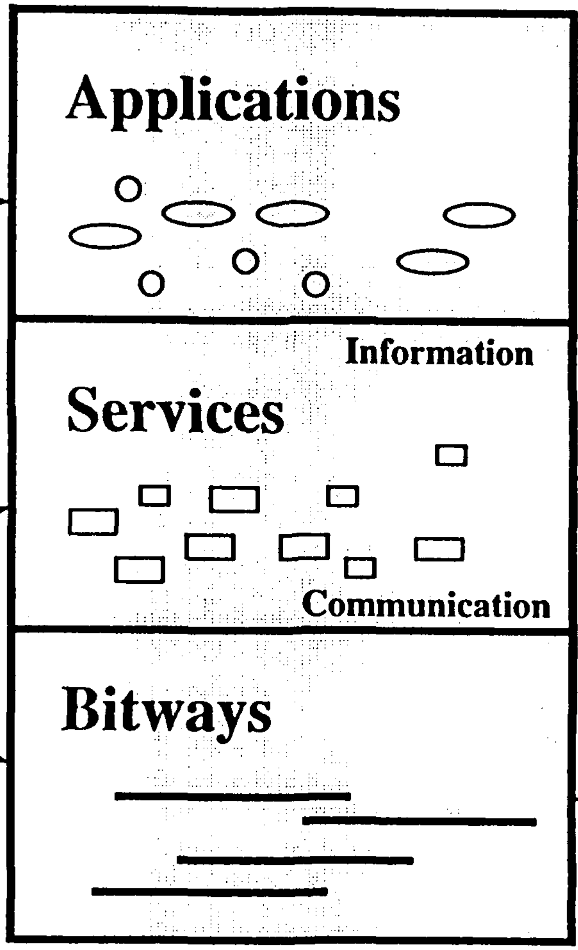
Enables rapid access to emerging technologies

The Program Layers

National Challenges (NC):
Achieve major new economies of scale.

NII supports all kinds of applications—not

National Information Infrastructure (NII):
Provide ubiquitous interconnected computing and communications.



Examples

- Design and Manufacturing
- Crisis Management
- Health Care
- Education and Training
- Environmental Monitoring
- Government Systems

- Multi-media multicast
- Engineering process support
- Distributed objects
- Electronic commerce
- Security and privacy service
- Virtual reality
- Information fusion
- Heterogeneous interoperation

Gigabit data communication
Common protocol support:
- Terrestrial fiber optics
- Terrestrial wireless
- Satellite radio and laser

Analog Interfaces

ARPA

Information Enterprise Elements

	Diversity What technologies require rapid growth, diverse supply	**Commonality** How capabilities are presented to client systems	**Utility** What is the value provided to the end user
Applications Capability to users	•	•	•
Services Information service foundations for applications	•	•	•
Bitways Communications channels among services	•	•	•
Projects:	smaller projects to develop innovative approaches to fundamental problems	larger scale integration of diverse technologies through consortia	diffusion of reduced-risk advanced technology to all sectors through pilot projects

III-B HIGH PERFORMANCE NETWORKS

DR. PAUL V. MOCKAPETRIS

Computing Systems Technology Office

High Performance Networks

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FOR OPEN PUBLICATION

JUN 1 8 1993 3

DIRECTORATE FOR FREEDOM OF INFORMATION
AND SECURITY REVIEW (OASD-PA)
DEPARTMENT OF DEFENSE

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June 23, 1993

93-S-223

What are the ARPA networking areas?

The networking research program is organized into complementary areas: "Internet Technology" which deals with the continued scaling of the present infrastructure, "High Performance Networking" which delivers new technologies and will meet the HPCC goal of gigabits in 1994-1996, and "Global Grid" which deals with the DoD's need for integrated, end-to-end systems of the future.

What are typical performance levels?

This slide shows growth in the expected performance of systems, and provides context for the target HPCC gigabit NREN.

Internet Multimedia & MBONE

The use of multimedia and video over the Internet is creating an escalating demand for bandwidth, even with simple off the shelf components.

How much is a Gigabit/sec?

A billion bits seems large, but when you consider the number of bits in the memory of a large machine, or a TV channel, or several other articles, it isn't so big.

High Performance Networks

This slide describes the different types of networks under development today, and the associated challenge and opportunity that is most important for each.

Complementary HPC Technologies

Maps out the major activities and their phasing over the next two FY and beyond.

HPC Deployment

Shows example networks and their locations.

ACTS Clients

Shows the projects, locations, and interrelationships between the various ACTS experimenters.

Strawman ACTS Deployment

Shows how we can combine satellite and terrestrial networks to make 6 ACTS ground stations serve over a dozen sites, instead of requiring extra ground stations.

WABitway concepts

Introduces acronyms.

WABitway

Network map for WABitway.

WAGnet

Shows the expected evolution of the WAGnet in terms of ground technologies.

Enablers and Enabled Work

Shows why each feature of the WAbitway is required, by naming what it enables.

What are the ARPA networking areas?

Internet Technology	Continued smooth scaling over 4 new orders of magnitude growth
High Performance Networking	High Performance NREN (gigabits in 1994-1996)
Global Grid	High Performance Networking applied to DoD end-to-end applications

What are typical performance levels?

Measure	Arpanet 1969	IP/TCP 1983	Today 1993	Future 1996
Trunk Speed	56 Kbps	56 Kbps	1-45 Mbps	2-10 Gbps
Interface Speed	56 Kbps	10 Mbps	10 Mbps	1 Gbps
Computers	4	200	1,486,000	10,000,000
Cooperating Net Managers	1	64	12,000	100,000

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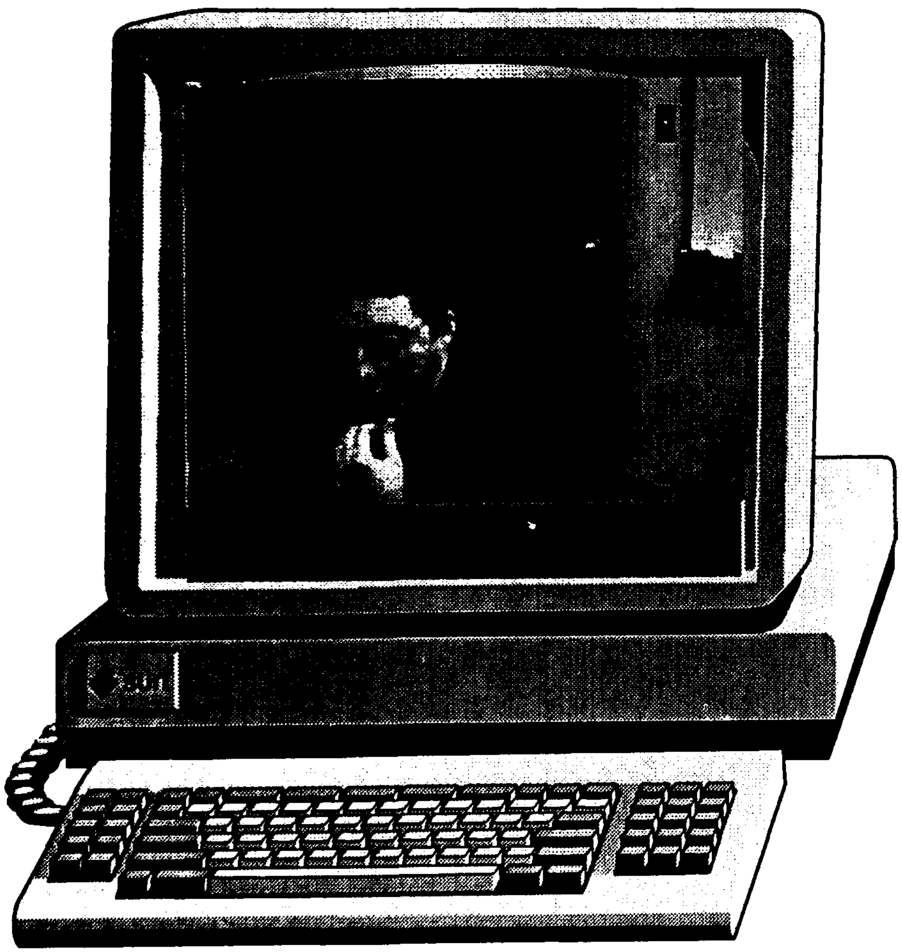
HPC

Internet Multimedia & MBONE



- Teleconferences with COTS equipment
- Global Multicast Backbone (MBONE)

Video is stressing the Internet today...

How much is a Gigabit/sec?

- 1000000000 bits/sec
- 100 Ethernets
- 22 Broadcast quality NTSC channels
- 10 High-quality images/sec (2048*2048*24)
- 4.5 Full NTSC TV channels
- .02 64K CM-2 / Delta memory images per sec
- .001/.14/1 Human [Rupert 91]

High Performance Networks

	High End Rate	Challenge	Opportunity	Example Effort
Common Carrier	2.4 Gbps	Culture Clash	Common Infrastructure	ARPA / NSF Testbeds
Satellite	.5 - 1 Gbps	Overcome Delay, Allocate Channel	Universal Access	ARPA / NASA ACTS
LAN	1 Gbps	Low Cost, Standards	Bootstrap	ARPA / NRL Fore
Wireless			Portability	
Broadcast		Group Mgmt, Ack Method	Dissemination	DARTnet PARC
Optical	10 Gbps	Electronic Bottleneck	THz Bandwidth	All Optical Consortia
UTP	100 Mbps		Perceived Infrastructure	

ARPA

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HPC

Complementary HPC Technologies

		FY93	FY94	Beyond
Prototypes	Industrial SONET / ATM	100 Mbit ATM	1 Gbit ATM 155 Mbit ATM / SONET	Integrated Services at > 622 Mbit
	Satellite		622 Mbit SONET	Global Grid Components
	Optical	Component Experiments	All Optical	Optical Internets
Testbeds	SONET / ATM	100 Mbit LANs	622 Mbit LANs / WANs 2.4 Gbit SONET	
	WABitway	100 Mbit	622 / THz	THz bitway
	Optical	WDM	WDM & 10-100 Gbit	THz initiative
Applications	Medical		ACTS & MAN	
	Simulation	WAGnet		
	Imagery	Integrated Imagery on MAGIC Testbed	Imagery distribution via WAN, LAN, ACTS and Internet	Imagery as typical object
Integration		LAN / WAN interconnect with flow control	Open base for realtime & guarantees	Foundation for Global Grid

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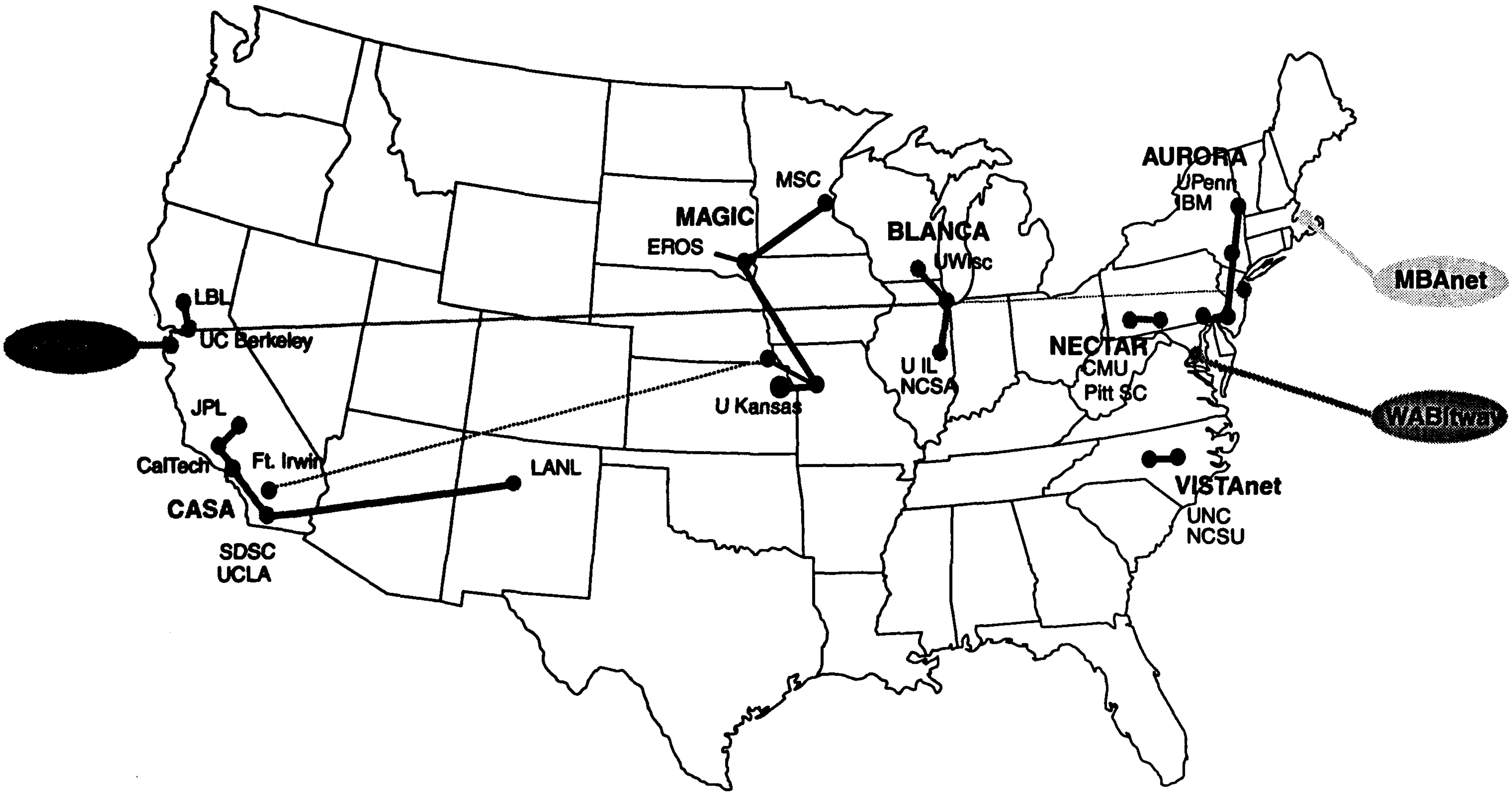
HPC

HPC 93 Deployment



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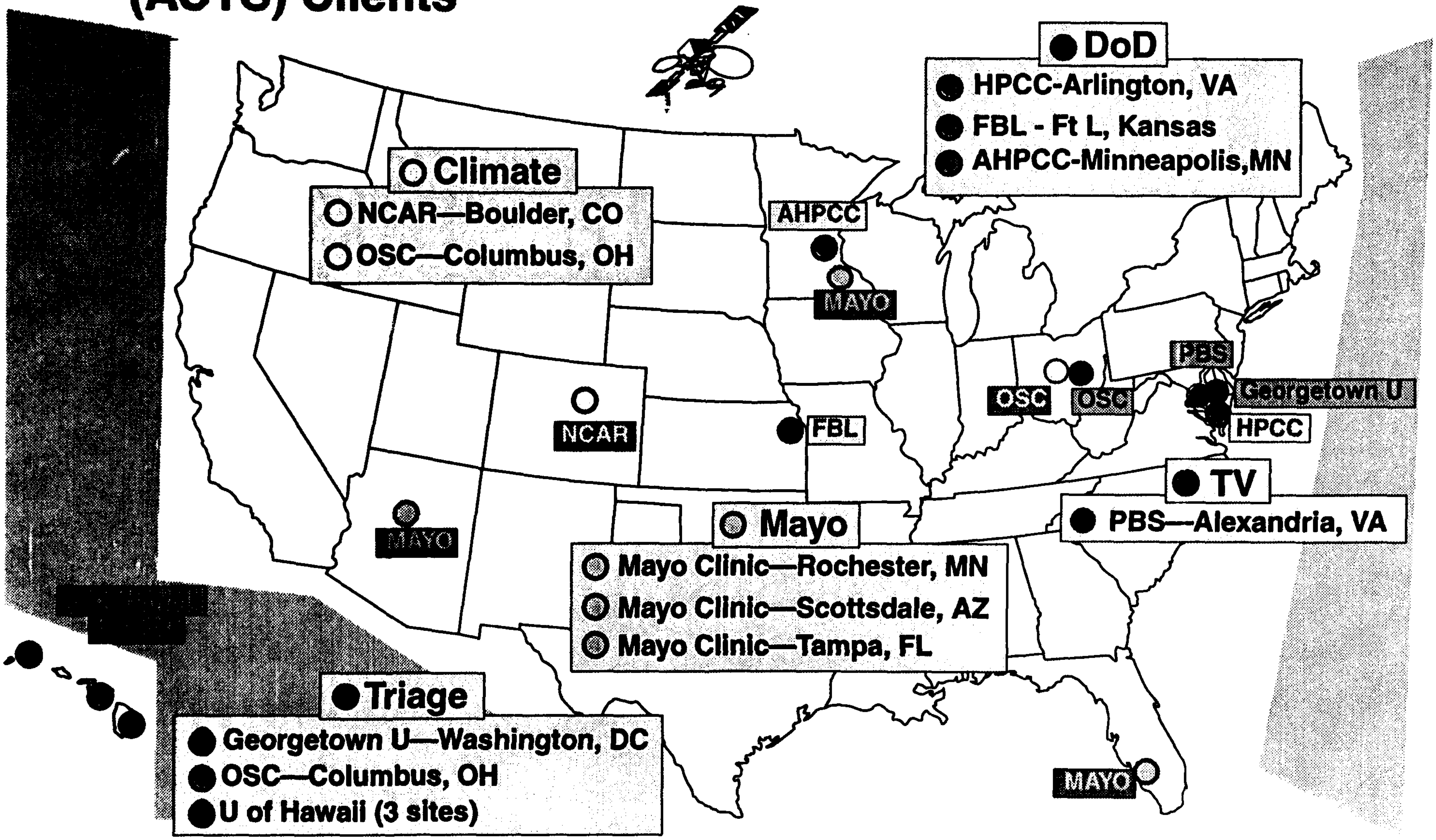
HPC

Advanced Communications Technology Satellite (ACTS) Clients



● DoD
- HPCC-Arlington, VA
- FBL - Ft L, Kansas
- AHPCC-Minneapolis,MN

○ Climate
- NCAR—Boulder, CO
- OSC—Columbus, OH

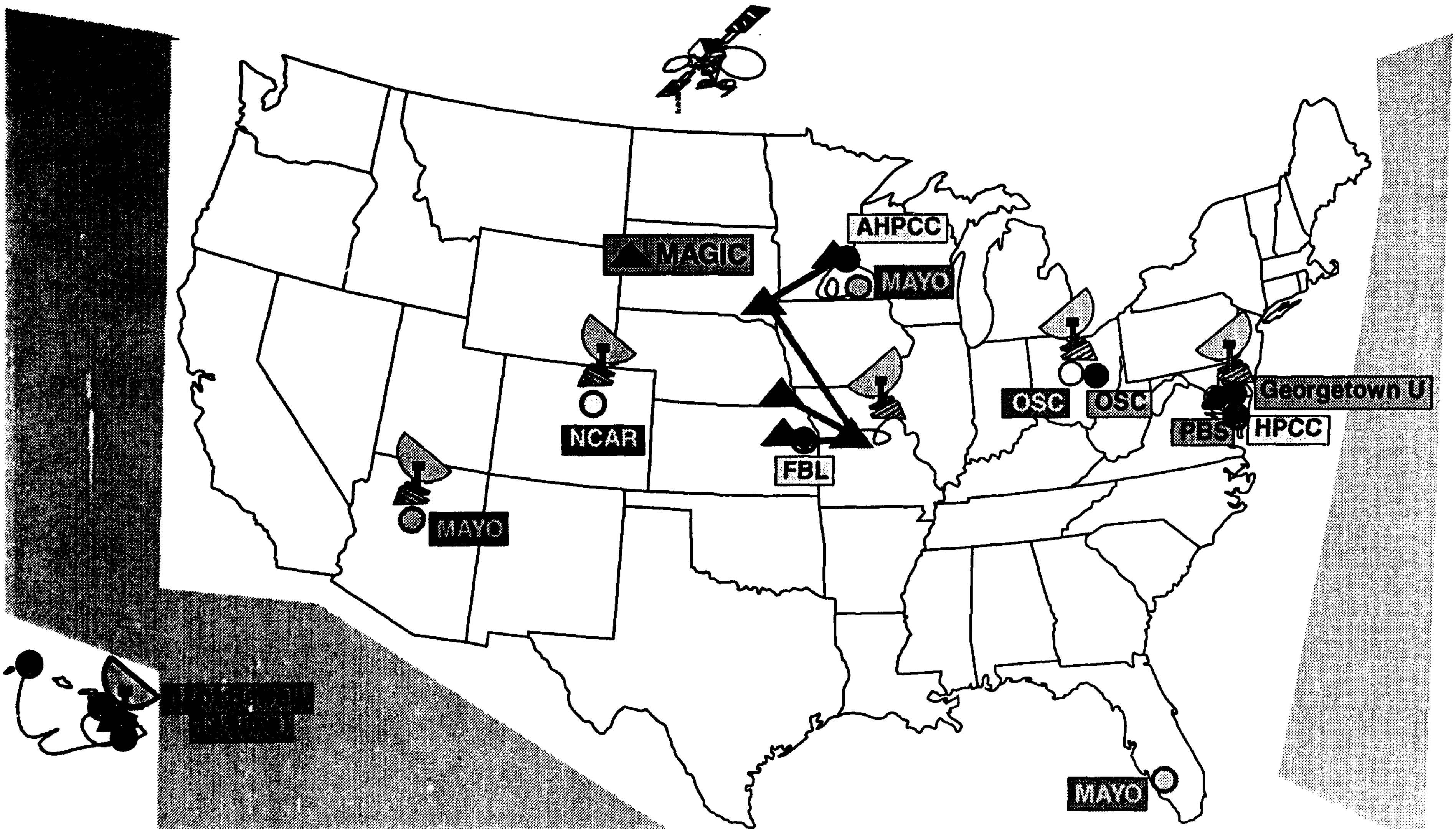
● TV
- PBS—Alexandria, VA

◎ Mayo
- Mayo Clinic—Rochester, MN
- Mayo Clinic—Scottsdale, AZ
- Mayo Clinic—Tampa, FL

● Triage
- Georgetown U—Washington, DC
- OSC—Columbus, OH
- U of Hawaii (3 sites)

Computing Systems Technology Office

Strawman ACTS Deployment



WABitway concepts

use:

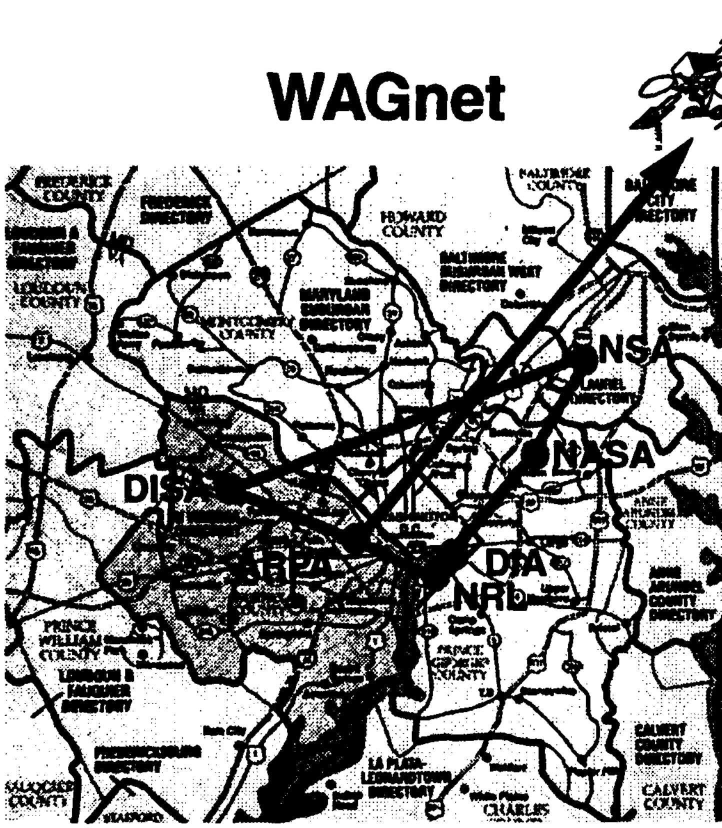
SONET = Synchronous Optical Network

ATM = Asynchronous Transfer Mode

Bitway = Mixed Binary “Pipe”

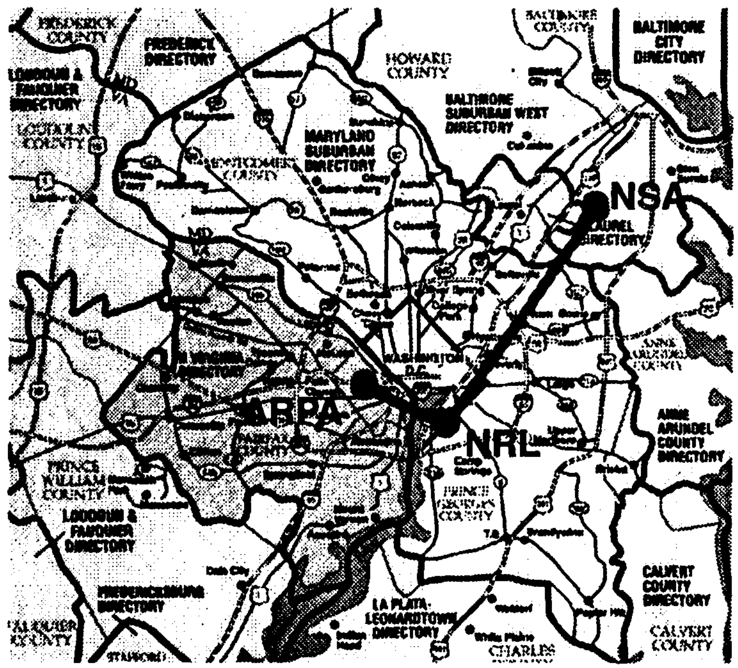
WABitway

WAGnet



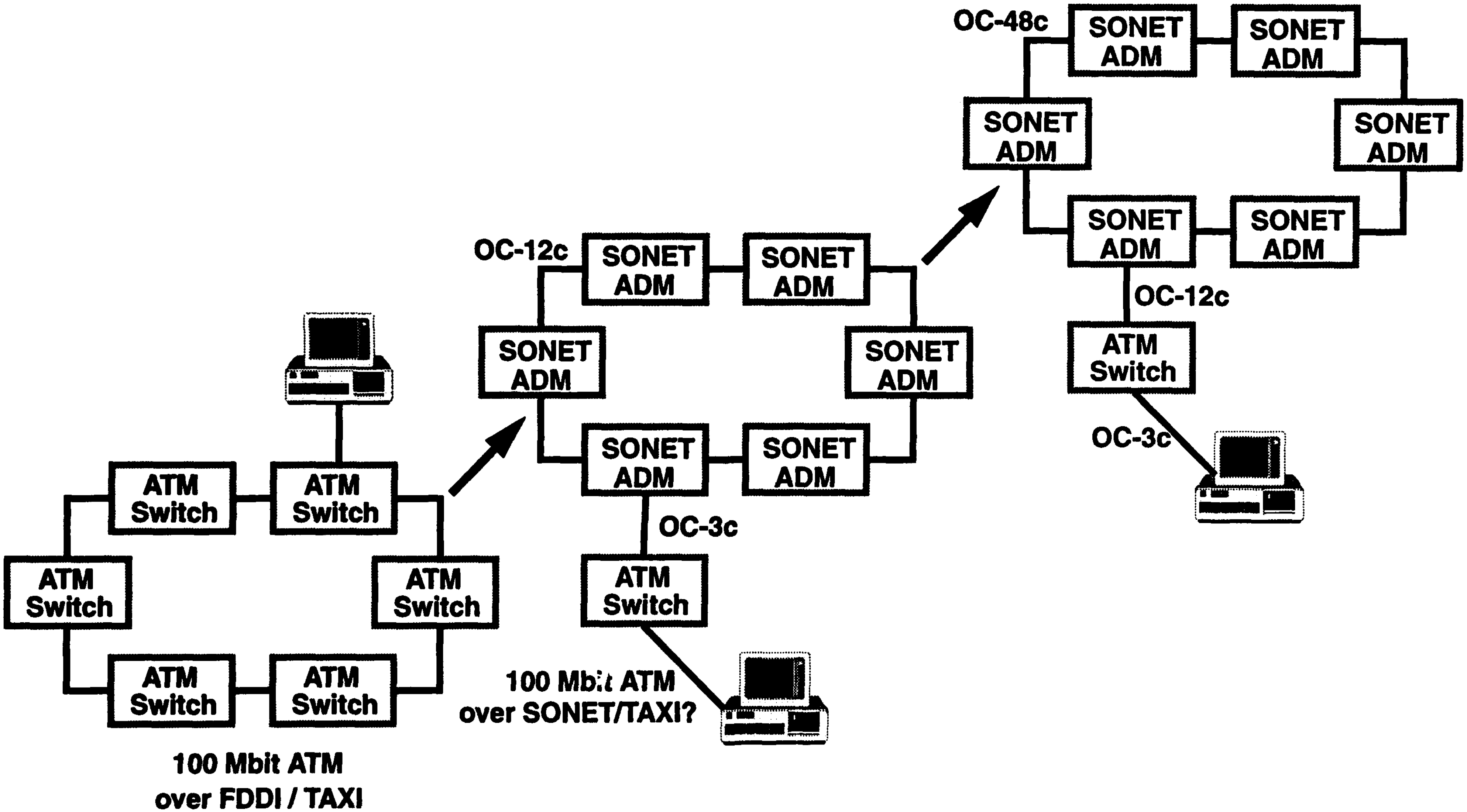
OC-12 / OC-3 SONET Ring ATM testbed

TFnet



Tbps Fiber Network

WAGnet Evolution



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Enablers and Enabled Work

	Feature	Enabled
ATDnet	6 Sites	Networking *is* Multiparty (DISA, NASA, DIA, NRL, NSA, ARPA)
	SONET	SONET Experience
		Link Encryption
		Configurable
	ATM	Key-Agile Encryption
WABitway	SONET	ACTS Extension
	ATM	Distributed Backplanes
		ATM Open Control Software
	Dark Fiber	Technology Trade-offs, e.g., HIPPI extender vs. SONET
		WDM Technology Transition
	Long Haul	ATM end-to-end Service

III-C Embedded Systems

LtCol Brian Boesch

ADVANCED RESEARCH PROJECTS AGENCY
3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

June 21, 1993

MEMORANDUM FOR CSTO – WEIGAND/BOESCH

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

Reference is made to the following material submitted for clearance for open publication:

HPC SOFTWARE TECHNOLOGY

XXXXX The above referenced material was **CLEARED** for open publication by OASD(PA) on June 18, 1993, Case No 93-S-2228. All copies should carry the following Distribution Statement "A" as follows:

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CLEARANCE IS SUBJECT TO CAVEAT LISTED RE SLIDES 33 and 34 (LEFT BLANK)

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G. T. Winn
Technical Information Officer

Attachments

93/06/17
09:12:33

Boesch-annotations.txt

Subject to the Govt below on Slides 33-34 (Hark)

HPC Software Technology

Overview -

This presentation discusses the general strategy of the HPC software program in three dimensions: Operating system support, compiler/library support, and support for embedded applications. The purpose of the presentation is to present overall concepts and directions and to stimulate interest and technical discussion, not to present specific technological details.

Slides 1-2 Overview and introduction

Slide 3 Goals and objectives of the HPC software program
The basic concept of scalability is introduced and the key priorities of the project: support for HPC architectures, acceptance by user base, and meeting DoD needs for real-time fault tolerance and distribution within a COTS environment are discussed.

Slides 4-9 HPC software concepts
The concept of single machine image is introduced and discussed. The physical realities of large scalable machines are discussed leading to the conclusion that systems composed of numerous "nodes" each of which is a potentially high performance computer acting in concert will virtually always outperform individual machines of either: single instruction multiple data or multiple instruction multiple data.
The ramifications of this conclusion is that the operating system, compliers, and libraries must create a virtual single machine from this set of independent processors. This virtual single machine (single machine image) must behave to the user much as a single computer would.

Slides 10-13 System Software (Operating system) Requirements
Briefly discuss the basic requirments and history of ARPA funded research into operating systems with a look to future additions. Specifically, discuss the current work in the area of extensions to the basic model to more accurately support the scalable single system image that was previously discussed. The two concepts introduced are: distributed services, and composed services. In distributed services, the services are not necessarily co-resident with applications on single nodes of the computer system, in composed services, virtual services such as very high speed stores may be approximated by composing large numbers of slow disks or stores.

Slides 14-18 Real-time
Discuss the introduction of real-time support into operating systems and in particular the introduction into scalable operating systems. Introduce the model of guest operating systems to handle very high speed events within the framework of an operating environment suitable for moderate speed real-time processing.

Slide 19 - Major Mach OS Participants
self explanatory.

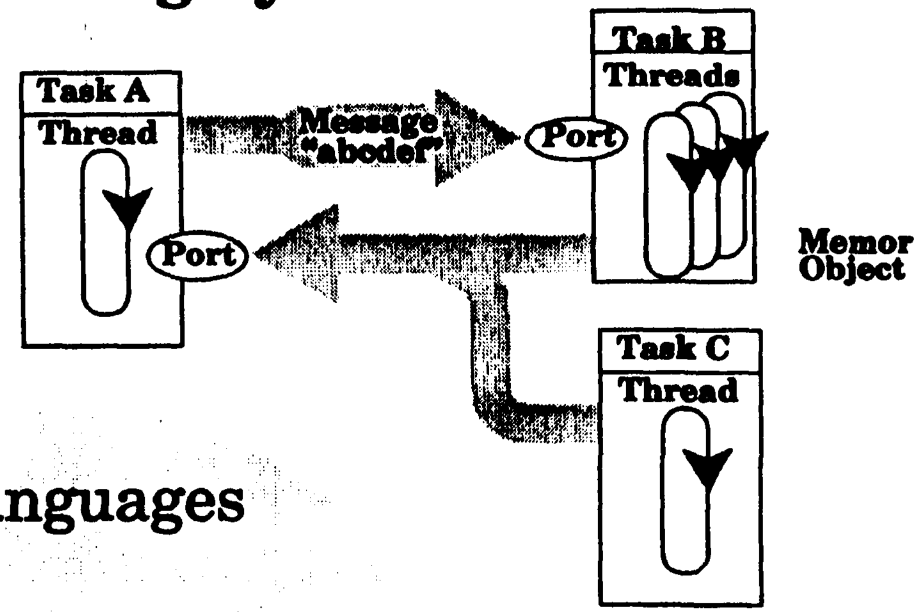
Slides 20-21 HPC model for language and library
Describe the general model for HPC library/compiler development and define the focus areas: compilation, performance analysis, programming support, particularly visualization, I/O support.

Computing Systems Technology Office

HPC Software Technology

Dr. Gil Weigand
LtCol Brian Boesch

Operating Systems and Services

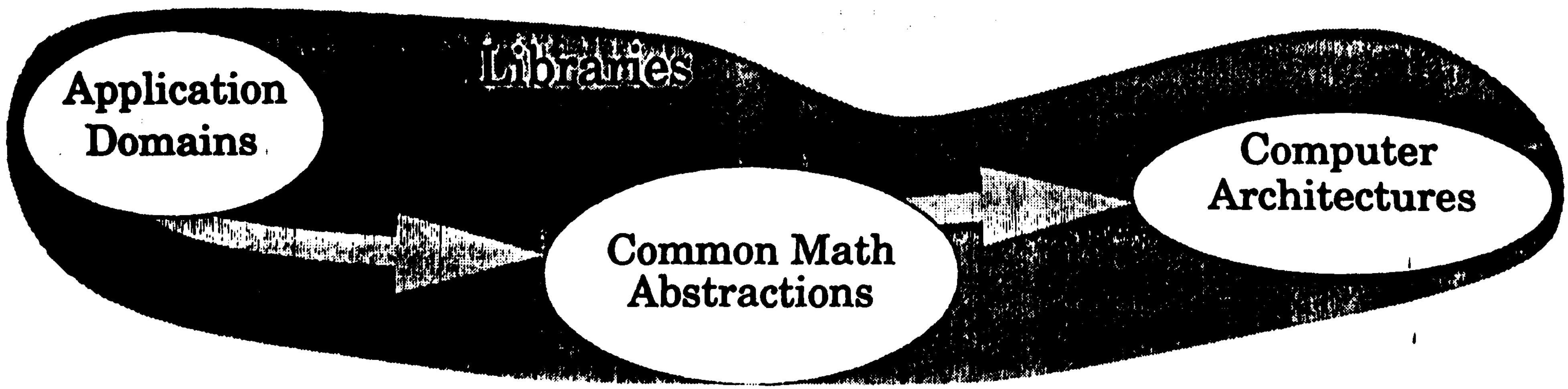


Languages

Ada

HPF

C++



Outline

- Scalable Systems Model
- Systems Software
  - real-time
- Scalable Libraries
- Programming Languages
- Integration of Workstations and Scalable Computers
- Technology Transfer

HPC Software Goals and Objectives

Develop scalable: algorithm design, software tools, operating systems enabling:

- wide use and peak performance of scalable computing systems
- rapid evolution of HPC architectures
- rapid transition of user base (commercial and military) to scalable platforms
- meet key DoD requirements: Trust, Real-Time, Fault Tolerance without fully custom implementations
- the same computational platform to meet a broad range of missions

early1990s

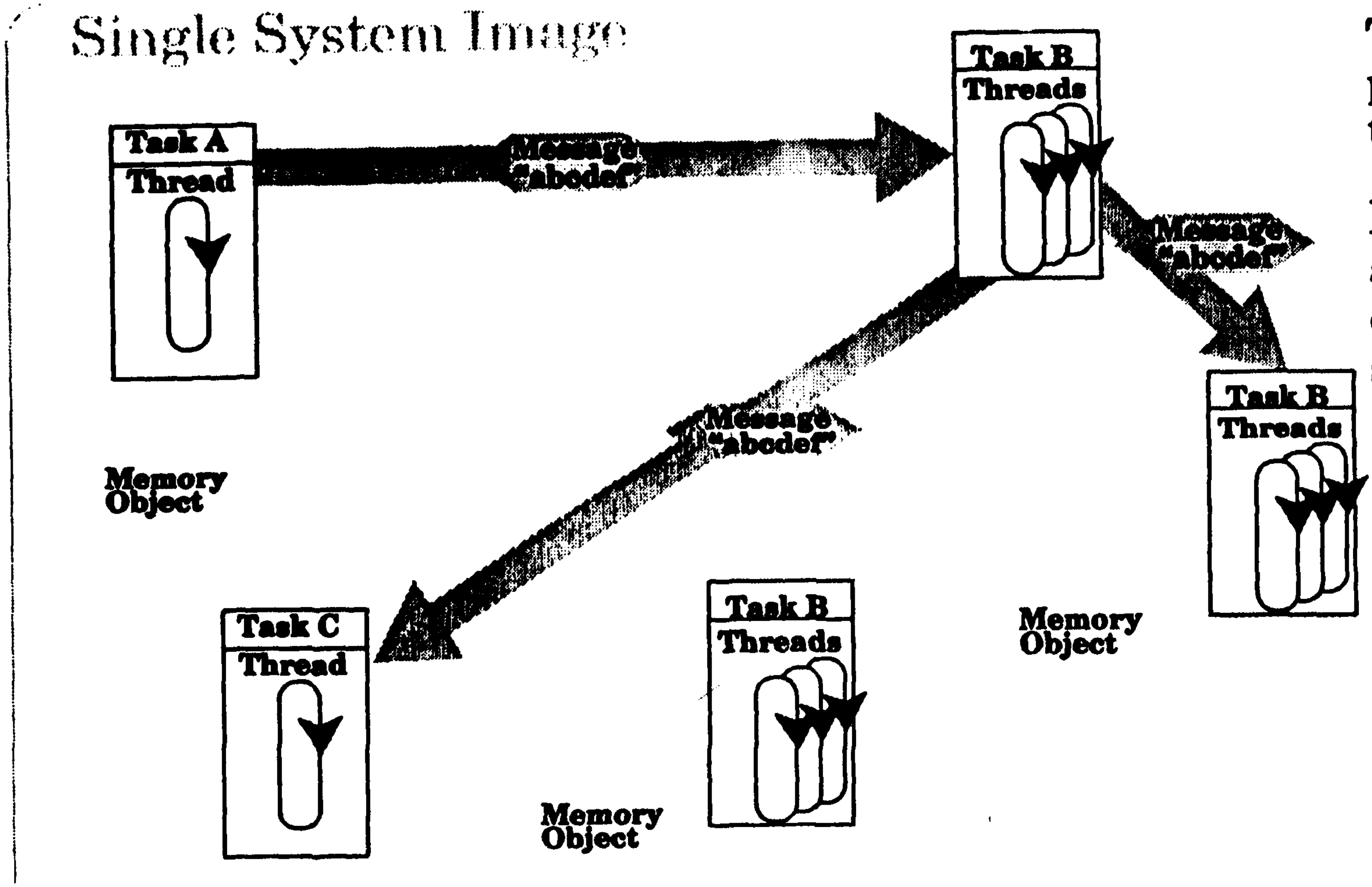
ported serial tools to parallel systems
parallel extensions to languages
initial attempts to parallelize OS

few node dependent libraries; parallel tools for performance analysis, dynamic parallel debug tools; foundations of generic scalable technology

Architecture independent generic technologies for parallel/scalable program development/execution; tools for collaborative development/computation common OS and services from lab to field

late 1990s

Scalable Systems Model
Programmer View



This model is phrased in Mach terminology.

However, abstractions are essentially the same in:

- NT
- Chorus
- Spring
- other µkernel systems

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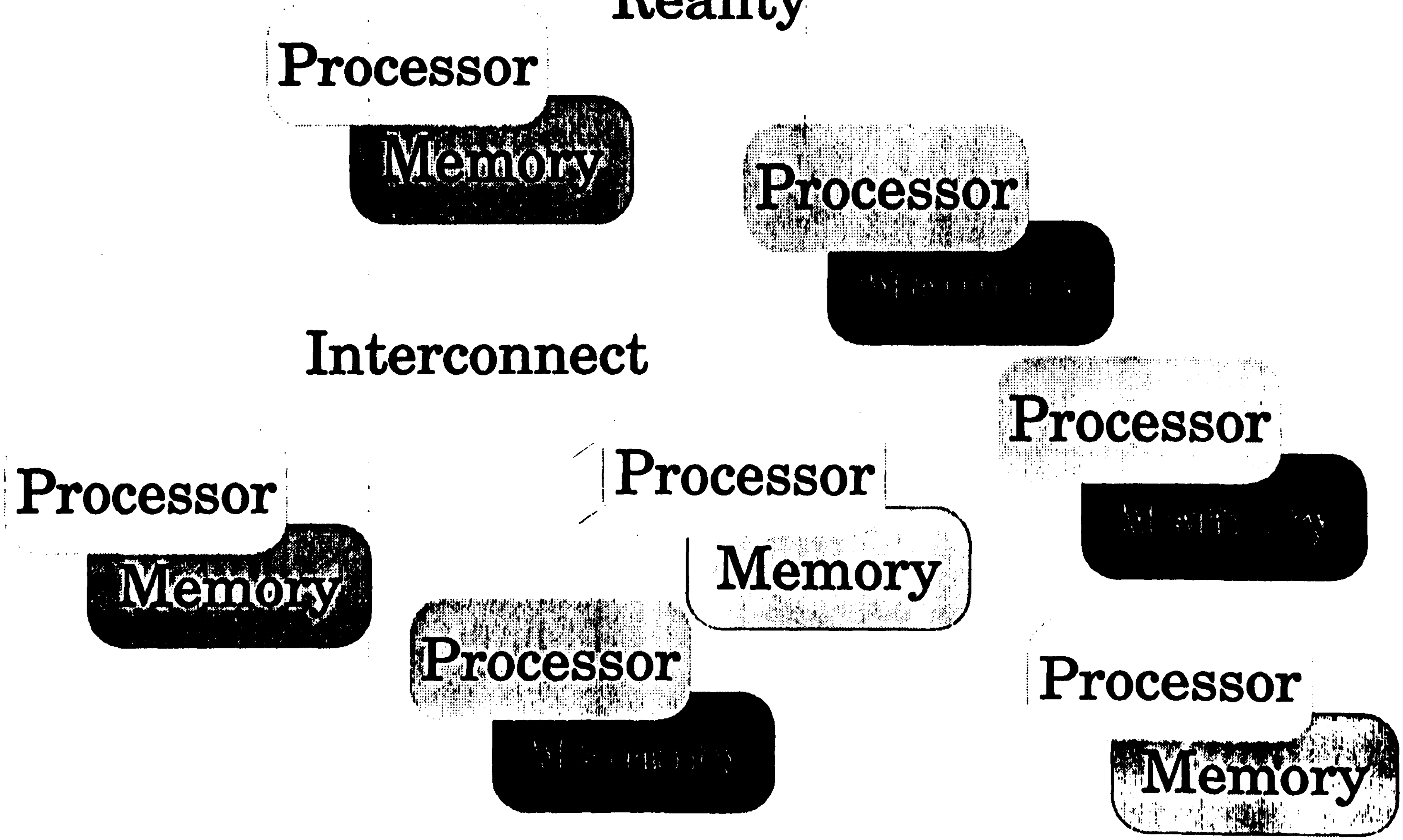
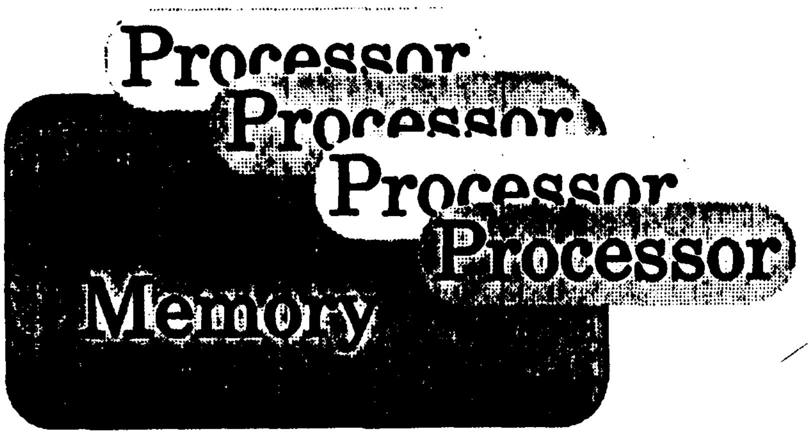
Scalable Systems Model “Reality”

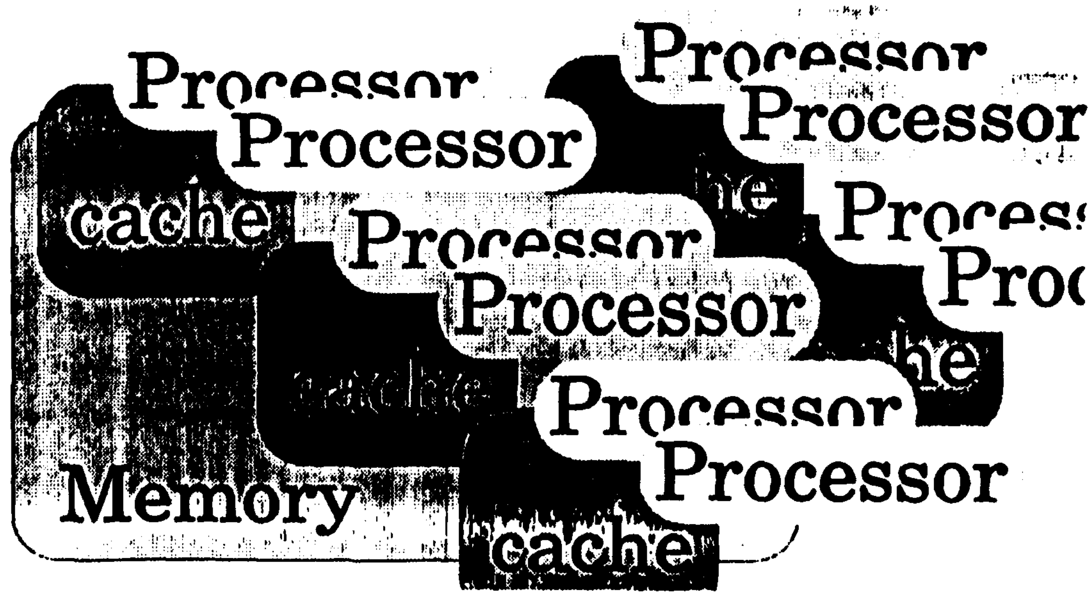


Why This Scalable Model

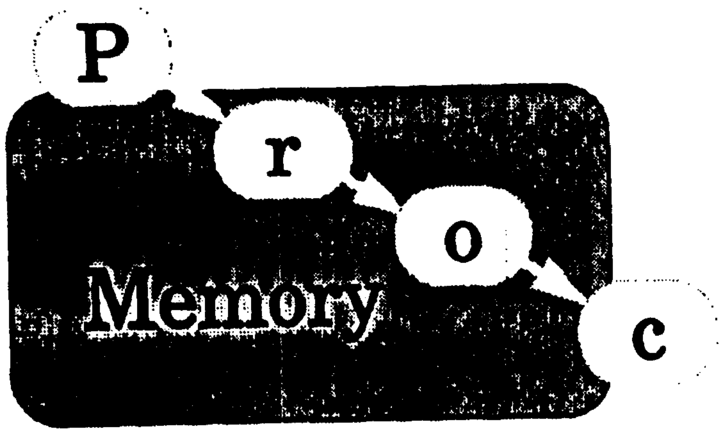


... because symmetric multiprocessors (fully symmetric shared memory) don't scale well beyond a few processors...

... because "simple" multi-layered caches don't scale well beyond about 30 processors



Why This Scalable Model(cont)



... because pipelining/ vectorizing scales well for some problems but not others ...

... LASTLY ...

... All of the above can be used in scalable systems. AND ...

ten nodes are faster than one ...

one hundred nodes are faster than ten ...

one thousand nodes are faster than one hundred ...

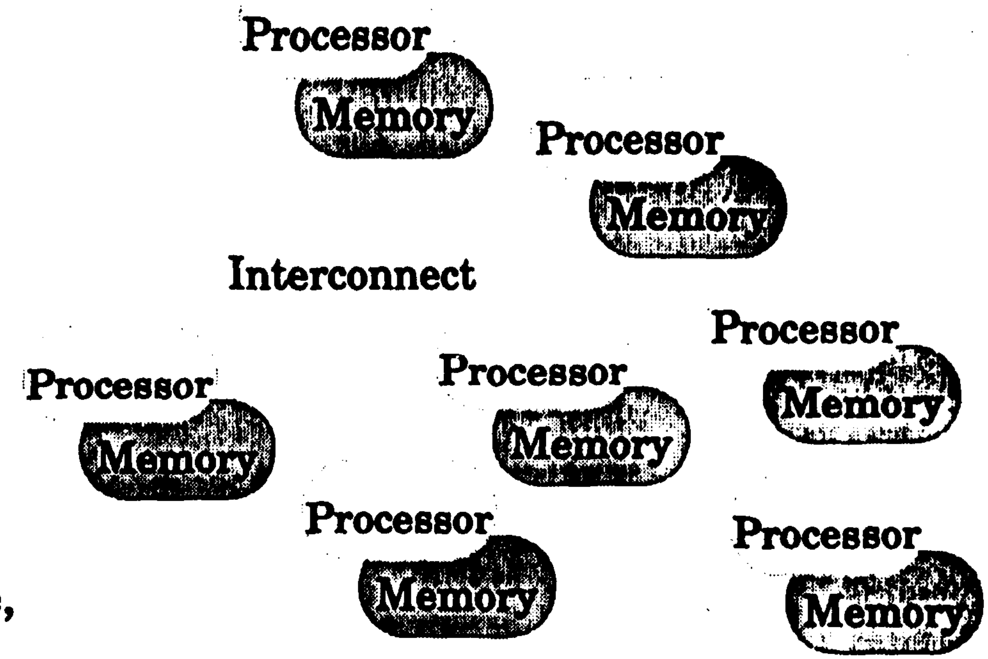
...

Which Vendors use this Scalable Systems Model?

Just about all HPC vendors use variations...

- Cray - T3-D
- Intel - Paragon
- Thinking Machines - CM5
- Masspar - MP-2
- Kendal Square - KSR-1
- NCube - NCube-3
- IBM - SP1

New systems in work too...



Vendors differentiate systems with various types of interconnect, processor architecture, hardware assist for messaging, hardware assist for non-local memory access, memory architecture/addressing structure, ...

ARPA

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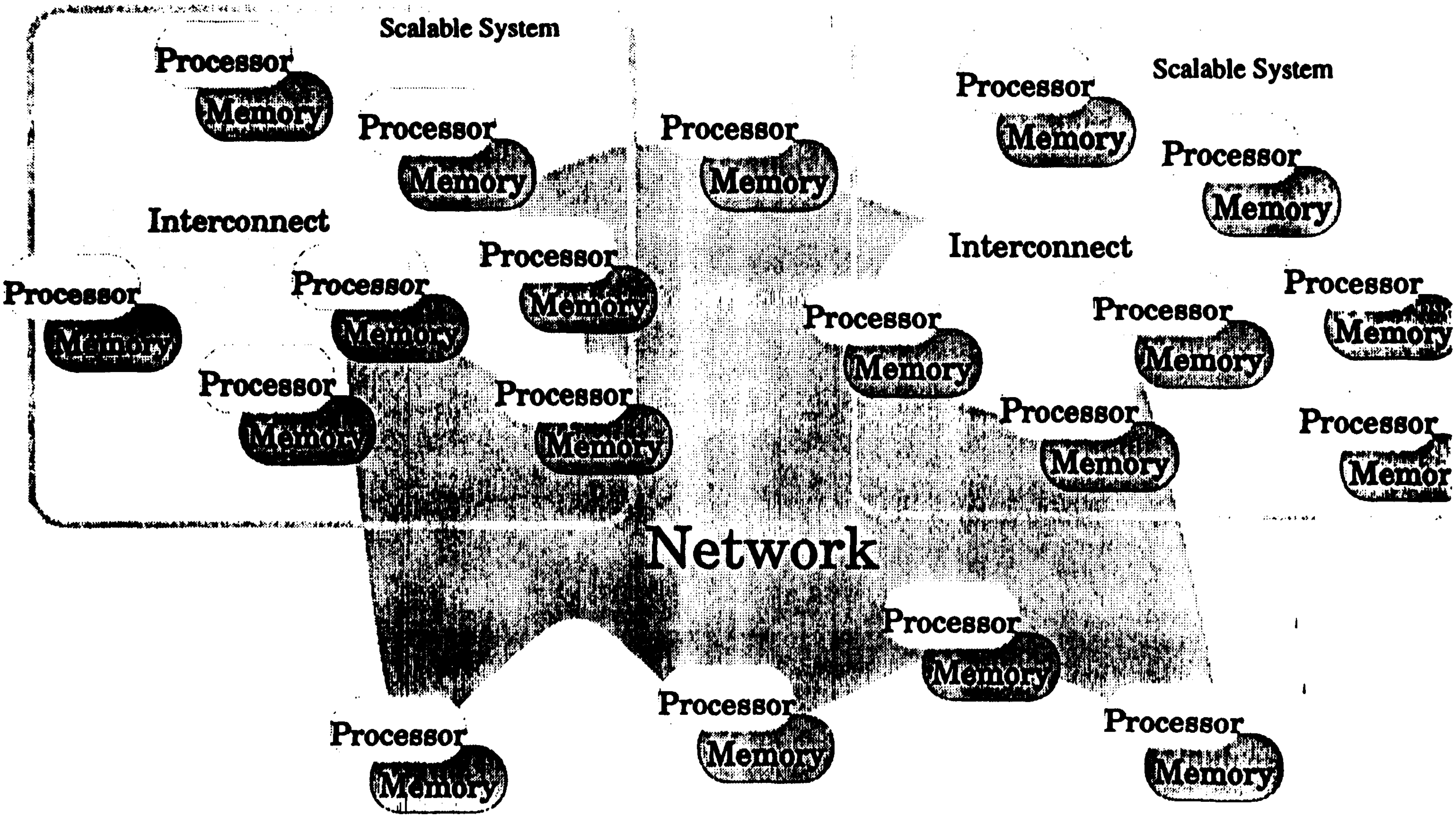
HPC

What about networks and workstations?



System Software

- Achieve a number of critical technology objectives:
  - •Security
  - •Scalability
  - •Distribution
  - •Real-Time
  - •Scalable Storage
- Achieve this through:
  - •Portable Micro-Kernel OS Technology
  - •Efficient ports for scalable systems and workstations
  - •Modular extensions

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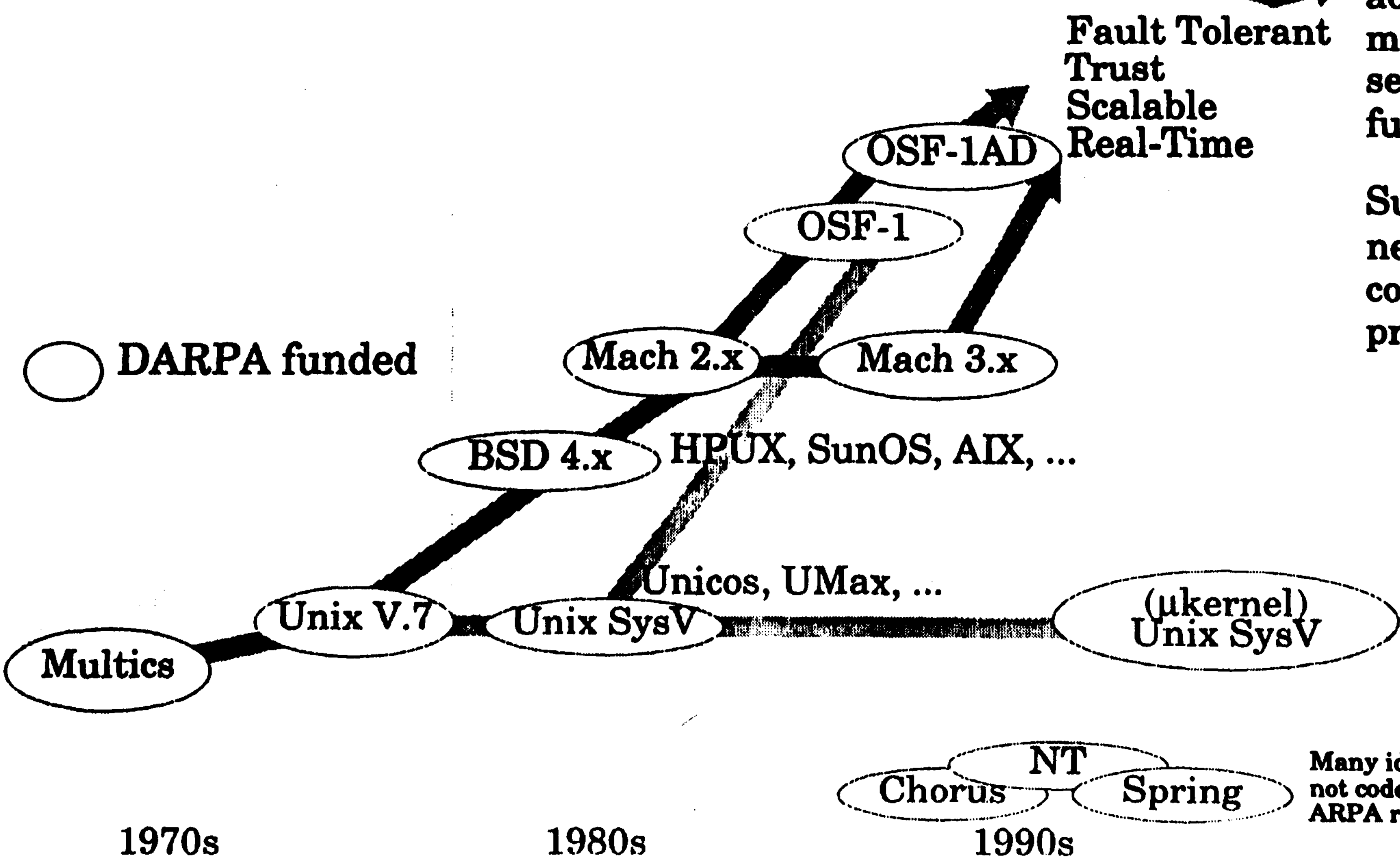
DARPA OS Research History



Exploit new hardware/ system advances wil[e] maintaining: seamless functionality.

Support DoD needs from commercial products

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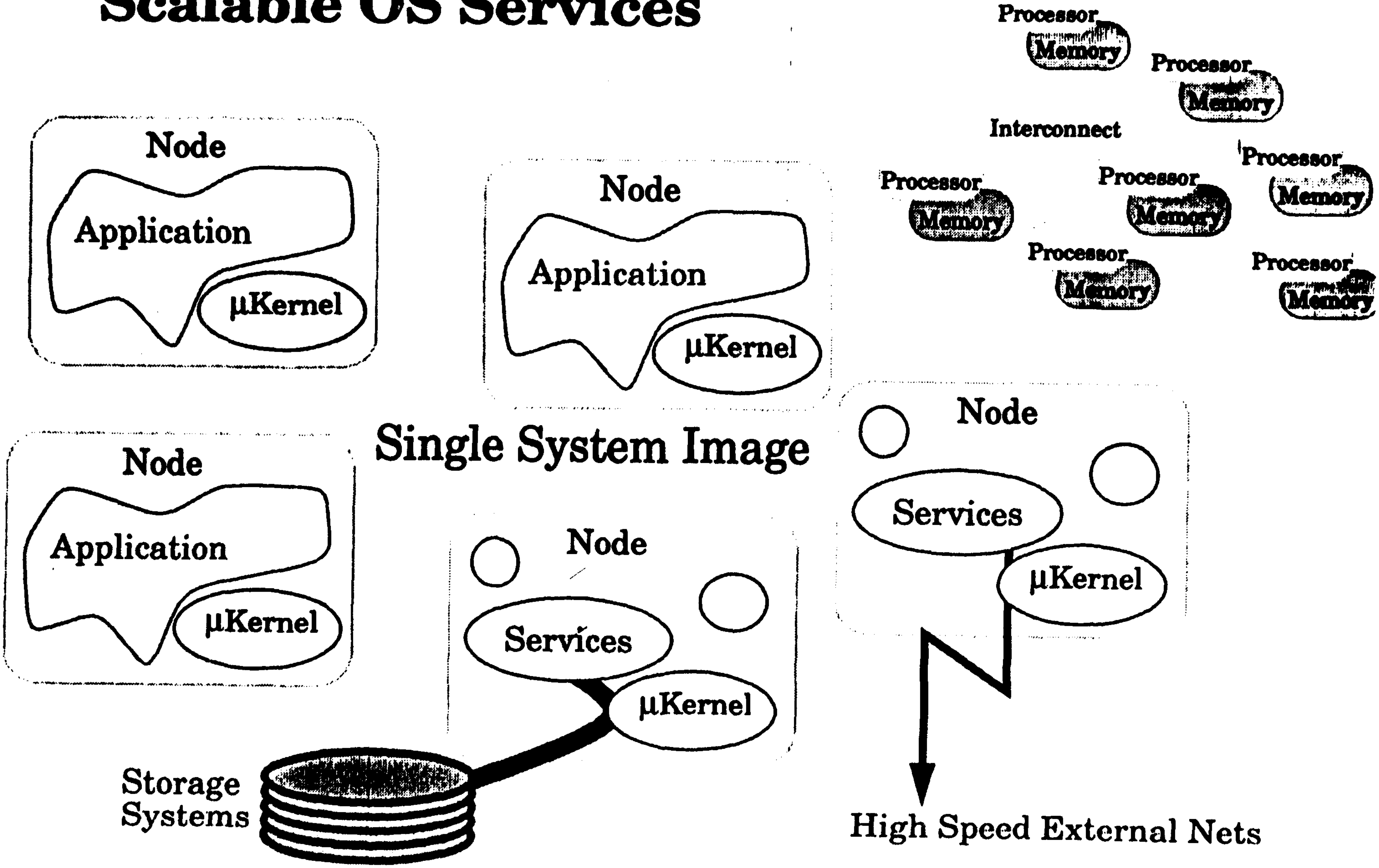
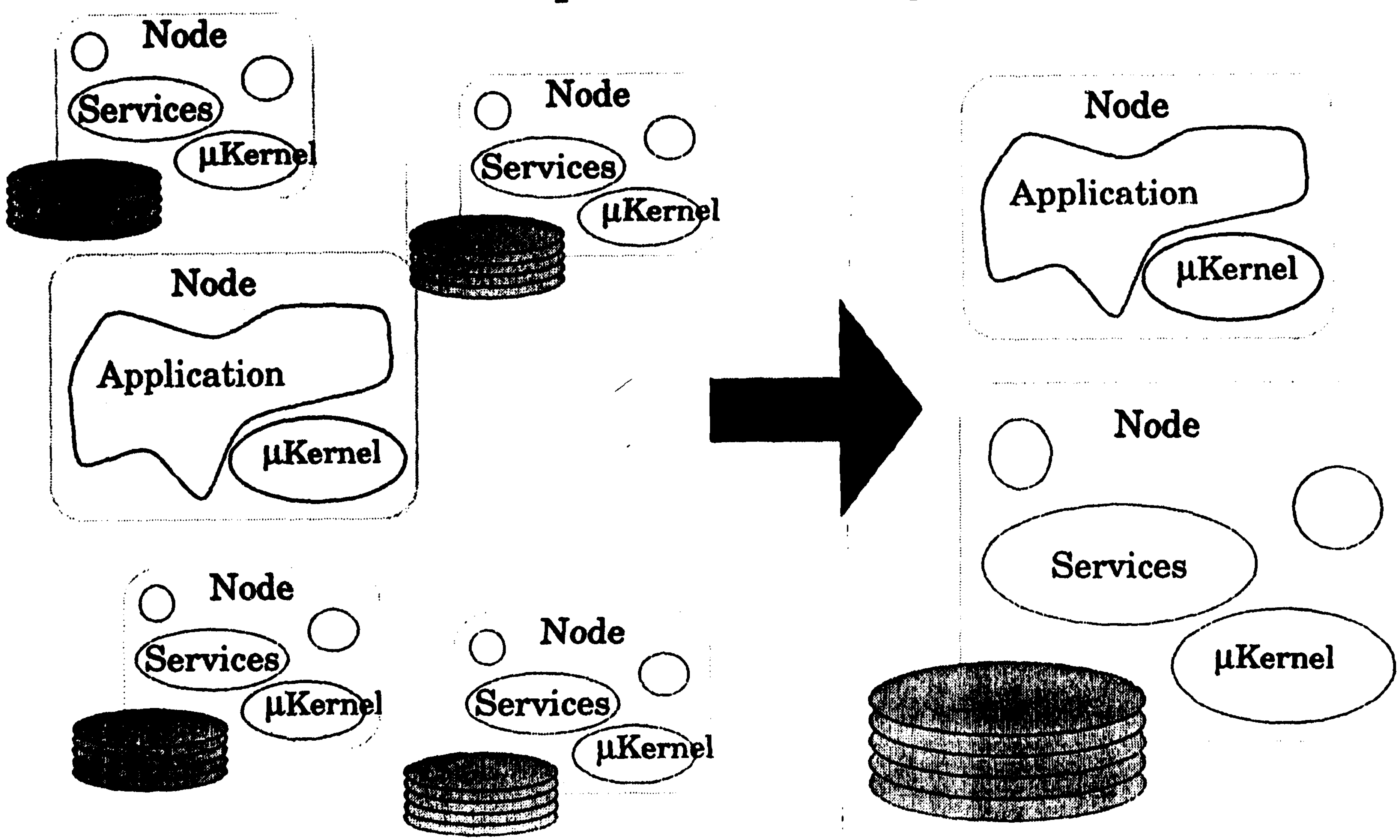
Scalable OS Services



OS Implications of Single System Image



Embedded Technology

Lives on and directly extends existing HPC technology in:

Operating Systems and Storage

Scalable Computing

Fast I/O Streams

Real-time

Fault Tolerance

Trust

Replication

Packaging & Prototyping Technology

Language, Run-Time, & Libraries

Real-time is not really "Real-Time"

Concept of a "real-time" OS is a chimera![1]

- Real-time needs of applications too diverse to be met with single solution
- No well founded theory on distributed real-time

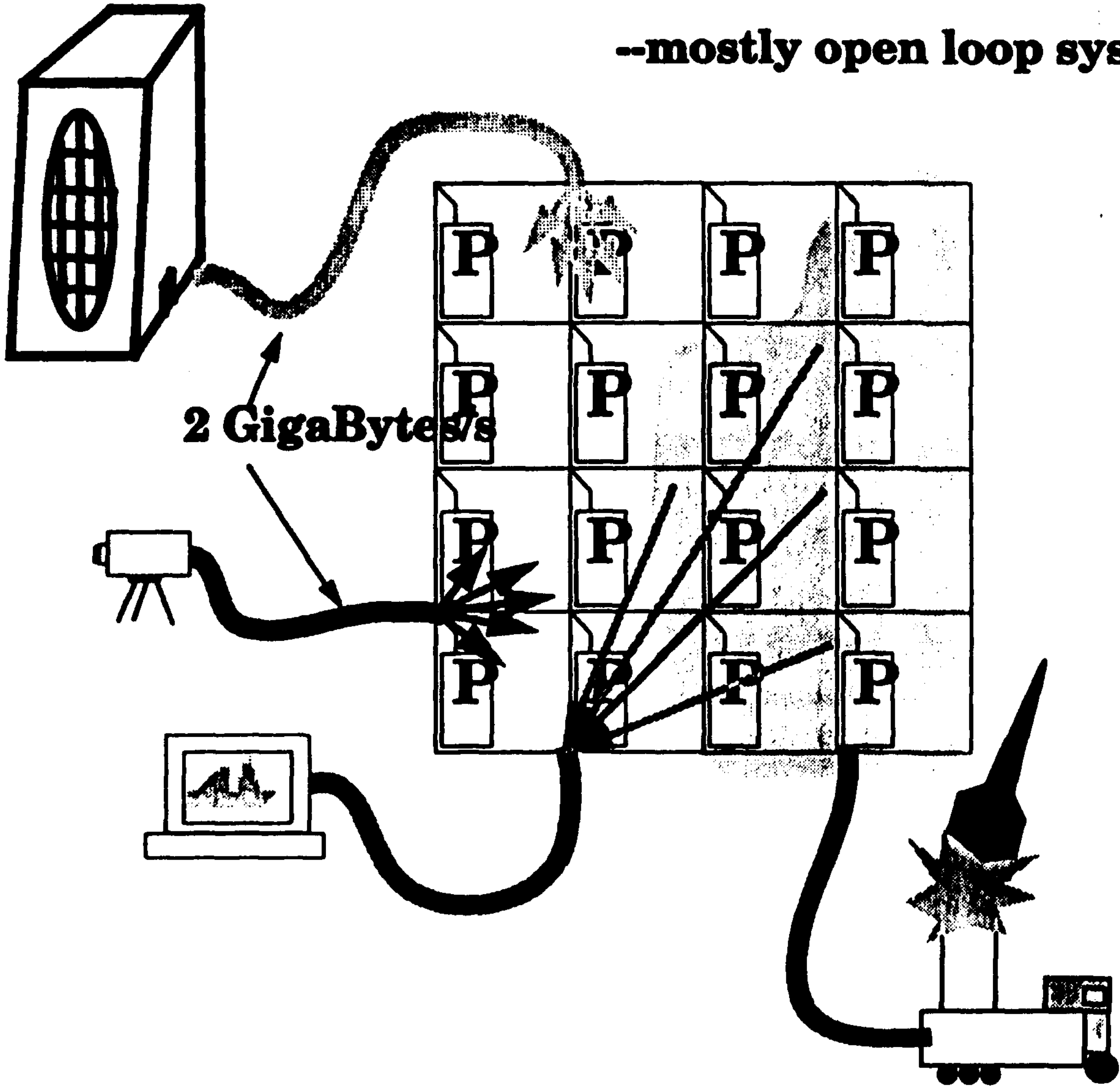
Kernel OS (Mach) approach

- OS is not and never will be a real-time OS
- OS will be augmented with a suite of tools and features to enable a very broad class of real-time applications to be developed

1. an imaginary monster compounded of incongruous parts; an illusion of fabrication of the mind; esp: an unrealizable dream

"Real-Time I/O Firehose"

--mostly open loop systems--



Need

Large data objects distributed to and from processors

Bandwidth guarantees

Latency guarantees between the producer and consumer

Data fusion

Real-Time Approach

Three "speeds"

- Fast - too fast for context switches
- Medium - OS protections and scheduler
- Slow - (often not considered RT by players)

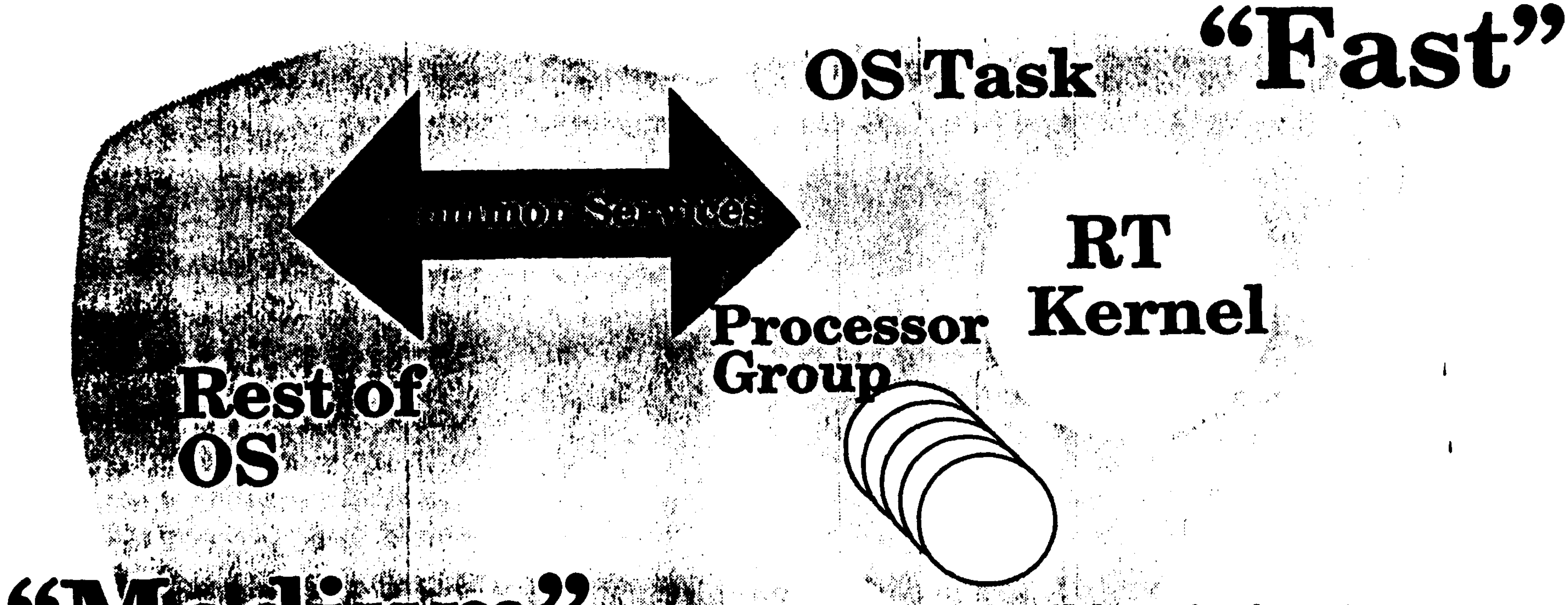
Approach for Medium

- OS features and scheduler
- Priority inversion prevention
- Decreasing lock times

Approach for Fast

- Guest OS
- Similar services to "regular" micro-kernel OS like OSF1-AD
- Access to OS services for "slow" operations such as files, ...

Real-Time Guest OS



- Flexible priority structure
- "Priority" inversion protection
- Real-time "roll back"
- User control of scheduler*

*part of basic OS, e.g., Mac

Major Mach OS Research Participants

- Carnegie Mellon Univ
  - Basic Mach abstractions
  - Very high speed I/O support
- Cornell
  - Fault tolerant communications
- Open Software Foundation
  - Integration with commercial "Unix"
  - Real-time kernel enhancements
- Trusted Information Systems
  - Trust enhancements - B3 Tmach
- Univ of Arizona
  - Flexible communication infrastructure
- Worchester Poly (CHPC)
  - Advanced real-time functionality
- HPC Vendors: Convex, Intel, Honeywell

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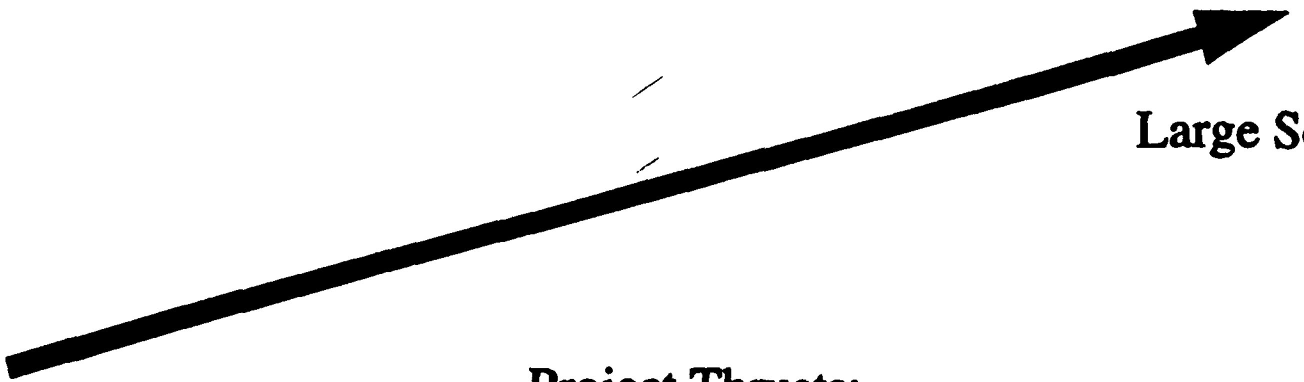
HPC Environments and Languages

Develop software, prototypes, and technology needed to effectively program the new generation of scalable HPC systems

Focus on common architectures, frameworks, and experimental platforms for scalable programming models



Large Scale HPC Systems

Workstations

Project Thrusts:

- produce several programming HPC environments
- computational tool technology

Computational Tool Technology

Focus on developing the next generation of computational tools technology, in other words, push the leading most edge of the research frontier:

- compilation
- performance analysis
- programming support, particularly visualization
- I/O support

Examples:

- Extensions to Fortran and C++ to specify parallelism
- Pablo--a performance instrumentation and analysis system
- New microprocessor compiler--Massively Scalar Compiler
- New transformations
- Back end specific optimizations--CM5 back end generated code within factor of 2 of best hand coded solutions

Language Extension Features

HPF and C++ provide mechanisms to allow the user to help the compiler by providing instructions about how to distribute data and computation across the system

Fortran extends the idea of Arrays as a memory object. Arrays are arranged, aligned, and then distributed across the machine

- TEMPLATE A(I,J)
- ALIGN B(I, J) WITH A(I+2, J-3), ALIGN C(k, l) WITH A(k,l), ...
- DISTRIBUTE A(*, "BLOCK")

pC++ extends the concept of a **Class*** by adding to the language a **Collection Class** which includes broad concepts of alignment and distribution

* an arbitrary data structure in memory which is a template for describing the object contents)

Scalable Libraries

User programs independent of

- machine size
- machine configuration,
- problem size, and
- almost as good as hand tuned

Two types of projects:

- emphasis on Library/Algorithm technology
- emphasis on whole Applications (CFD, EMP, materials, signal proc., ...)

+ some visualization (particular rendering)

Scalable Libraries

Typical Library

ScaLAPACK--Univ Tennessee, UCLA, Rice U., U.C. Berkeley, U. Illinois, Oak Ridge Nat'l Lab

- linear algebra solvers (LU, LL^T, QR) available through xnetlib/netlib
- sparse eigenvalue routines available via email: sorenson@rice.edu
- sparse iterative templates to be published in SIAM (summer '93)
- message passing standard (MPI) finished summer '93

Typical sustained performance

- 12 Gigaops on LU Decomposition on Delta system--512 processors, 32Gops peak
- 60 Gigaops on Linpack benchmark on CM-5 system -- 1024 node, 130Gops peak
- 18 Gigaops on CFD application on CM-5 system -- 512 node, 65 Gops peak

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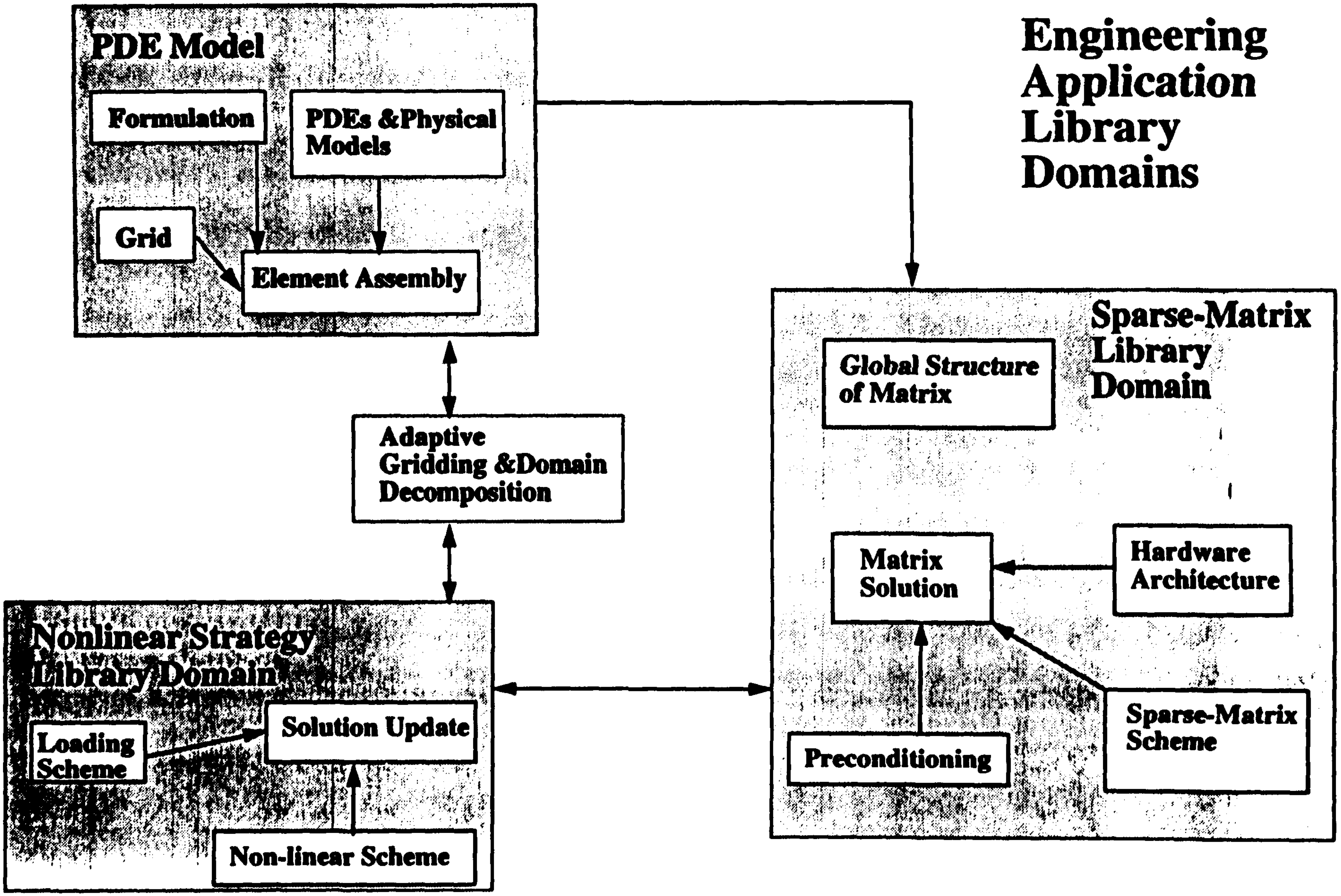
Engineering Application Library Domains



Integration of Workstations and Scalable Computers

- Network performance between workstations approaching intra-computer speeds
  - prototype network speeds of 70 MByte/second/link this year
  - intra-computer speeds less than 10X faster than networks
  - communication time dominated by software and memory speeds - NOT - network
- Extend single system image from inside scalable computer box
  - Seamless extension of computers boundary to workstations as necessary

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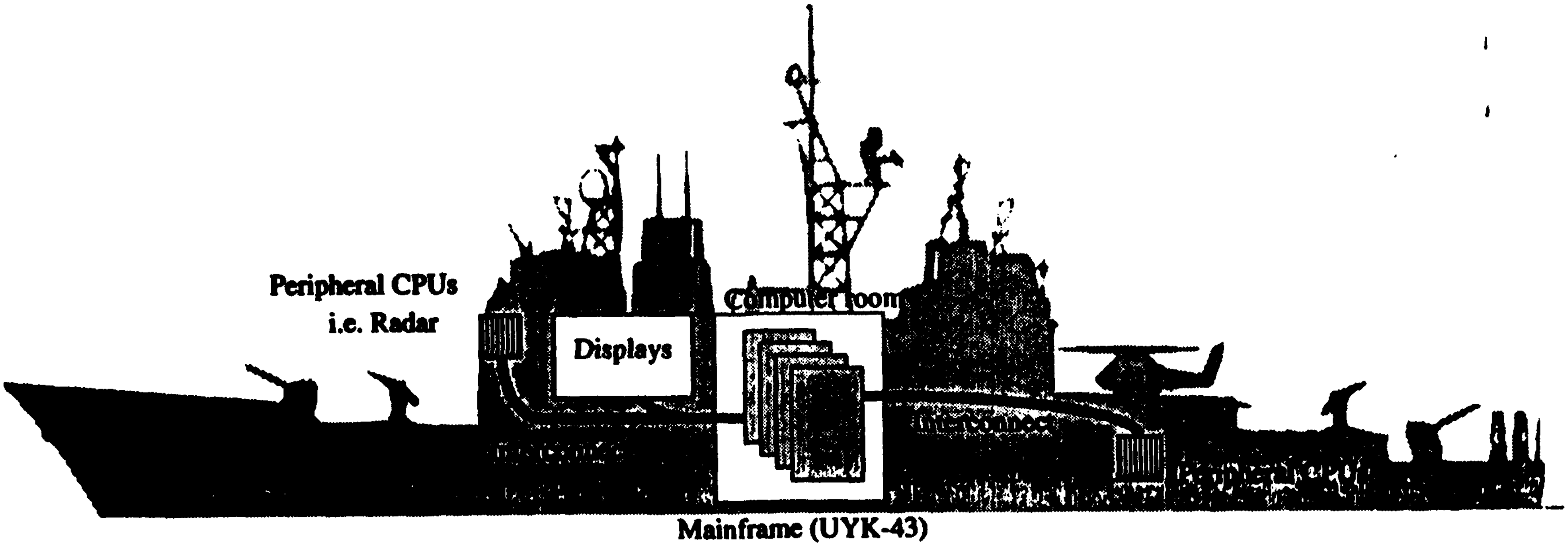
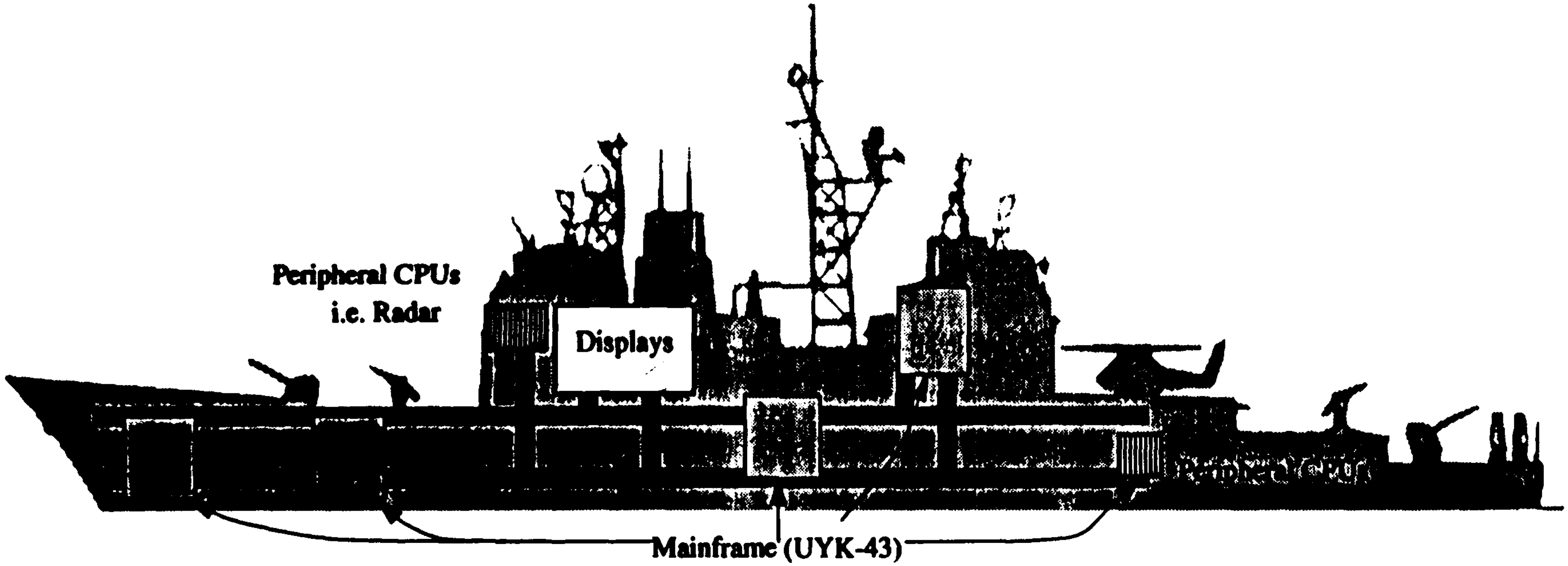


- Vulnerabilities
  - Mainframes
  - Peripheral CPU
  - Interconnection
- Federated Systems - Classic Reliability
  - Functional allocation to nodes
  - Reliability through replication of: mainframes, communication...
  - Process distribution difficult
  - Separate modes for degraded performance
  - Vulnerable to large scale damage (Exocet)



- Vulnerabilities
  - Mainframes
    degraded modes
  - Peripheral CPUs
    Backbone sufficiently redundant to be unlikely as vulnerability

- Federated Systems - Classic Distributed Computing
  - Reliability through replication of: mainframes, backbones
  - Processes located at distinct nodes
    (reorganization from damage easier, process distribution still difficult)
  - Separate modes for degraded performance
  - Backbones subsume conventional communication

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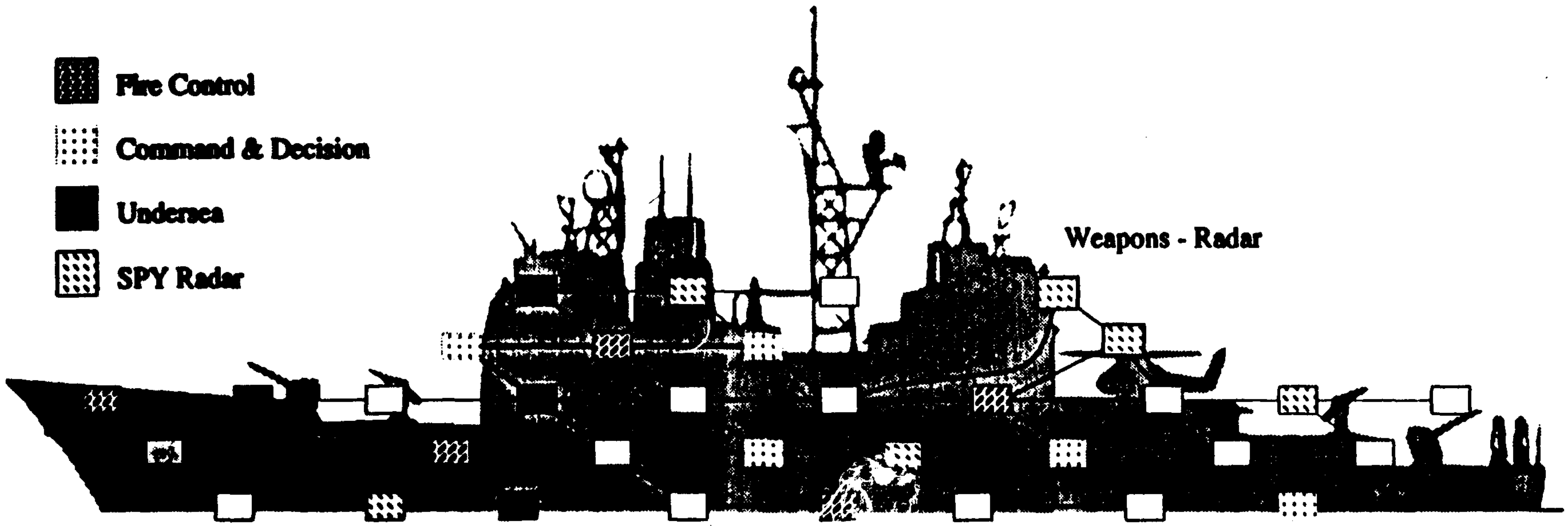

- Massively Distributed Computing
  - "Single computer" model
    - Migration of function to alternate nodes practical
    - Oversized computing - enables replication
    - Gigabyte/second interconnect integrated with system
  - Physically separated processors share tasks
    No data lost 'till all processors in group destroyed
    - Programming simplified by process sharing tools
    - Effectively invulnerable to battle damage

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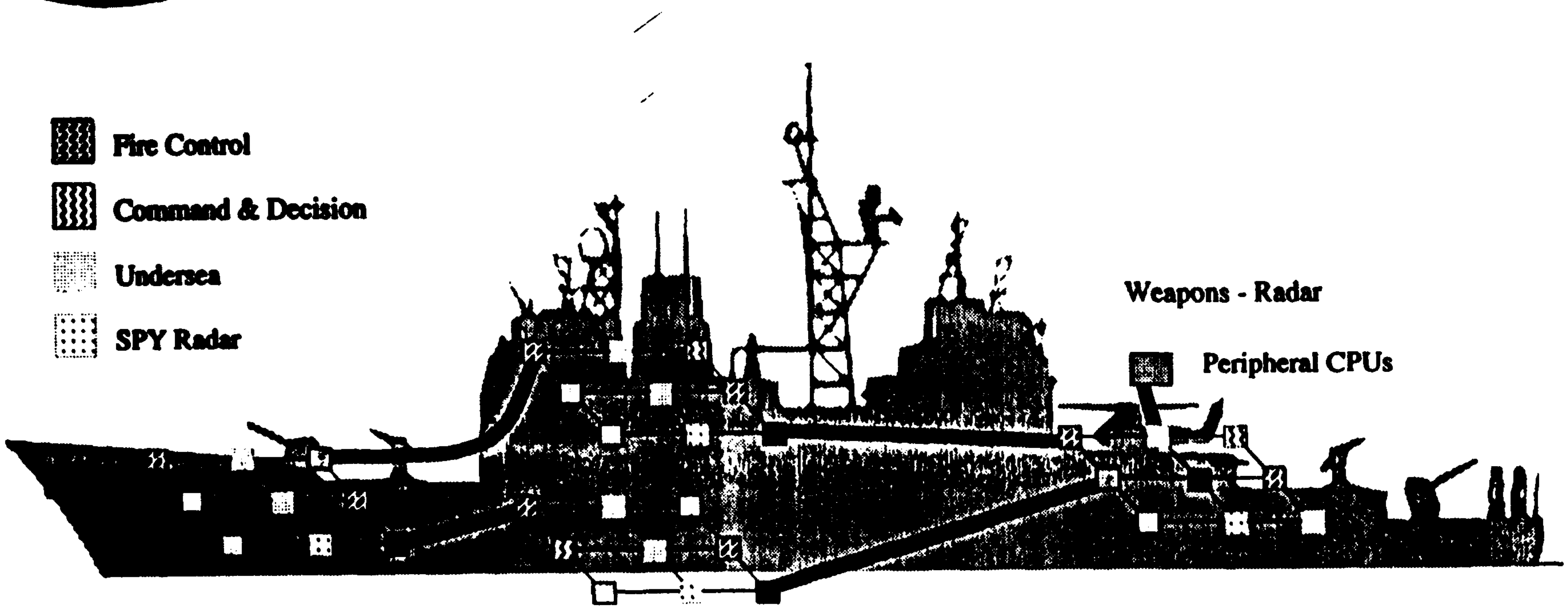

- Massively Distributed Computing
  - "Single computer" model retained
    - Migration of function to alternate nodes practical
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    - Gigabyte/second interconnect integrated with system
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    No data lost 'till all processors in group destroyed
    - Programming simplified by process sharing tools
    - Effectively invulnerable to battle damage

Hiper-D At year two of 5 year program

- Demonstrated Location Transparency
  - Applications developed on single computers and moved to multiple computers without change.
- Demonstrated Initial Fault Tolerance
  - Basic technology to support replication
  - Guaranteed consistency through advanced software libraries
- Demonstrated portability of software written on "commercial" portable operating systems
- Developed suite of architectures for Aegis using Hiper-D technology

Conclusions

- HPC Technology is manageable
  - Computing Model Appropriate to broad class of problems
  - Operating System, Compiler, and Libraries
    - Initial results in isolating applications from machine architecture favorable
    - Specific applications have been ported over next two years breadth of applications supported will grow substantially
- HPC for Embedded Applications
  - Computing systems directly usable for many problems
    - computationally intense problems with fairly regular structure
  - Hiper-D will demonstrate ability to do "classic" C3
    - HPC architectures can meet real-time objectives
    - Scalability enhances rather than detracts from buildability
- Research progressing
  - Enable virtually architecture independent applications
  - High degree of support for embedded needs

III-D SOFTWARE ENGINEERING

MR. JOHN T. FOREMAN

ADVANCED RESEARCH PROJECTS AGENCY
3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

June 16, 1993

MEMORANDUM FOR SISTO - FOREMAN

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

Reference is made to the following material submitted for clearance for open publication:

SOFTWARE ENGINEERING

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G. T. Winn
Technical Information Officer

Attachments

SOFTWARE ENGINEERING

ARPA SYMPOSIUM

John Foreman
Software & Intelligent Systems Technology Office
Advanced Research Projects Agency
FOREMAN@arpa.mil
703 243-8655
23 June 1993

The following are intended to provide very brief descriptions of the slides in the software engineering presentation. The title of the slide is usually the first item in each entry

Outline - self explanatory - set context for the presentation

Purpose - slight elaboration of the outline chart and it may replace the outline in subsequent versions.

Software Legacy - a pictorial slide to be used as an illustration of the software problem - specifically the massive complexity of large software systems.

Problems - This is not really a slide, but is something of an elaboration of the specific problems of the previous chart - as such it will be eventually be removed.

Program Manager Challenge - This is another slide to focus on the issues and challenges of software development

What is a million loc - This slide will be used to provide further focus on the idea of SW complexity and try to provide a physical representation of just how big 1 million lines of code is.

SISTO Vision - the earlier slides are designed to provide an overall context to the SW problem - this is a 1 chart view of how we (SISTO) believe things must progress over time.

Software Engineering in SISTO - The rest of the presentation is

focused on what the SISTO programs are. This chart shows the hierarchy and sets the stage for more detailed discussion of each program.

Next 6 or so slides (individual program discussion) - In each subsequent slide (ie, the next 6) we will address the focus of each program and how the programs address the previously stated vision. There is one additional slide after the STARS slide which shows some of the activities ongoing in the Army demo project. This chart is formatted similarly to the SISTO vision chart and will be related back to that chart as an example of work in progress.

Key Software Concepts - This slide is a summary of the talk - our envisionment of where the software community needs to be.

Software Technology Investment Strategy - Another view of our vision, but I will use this to stress the flow from science ---> consumers, the role industry can have, and discuss the need to have metrics based evaluations as part of the improvement process.

------- End of Forwarded Message

Outline/Purpose

- Review Key software engineering challenges
- Define Vision for future software development
- Highlight Current Software Engineering Strategy and Activities
- Summary/Opportunities for Industry

Software Legacy

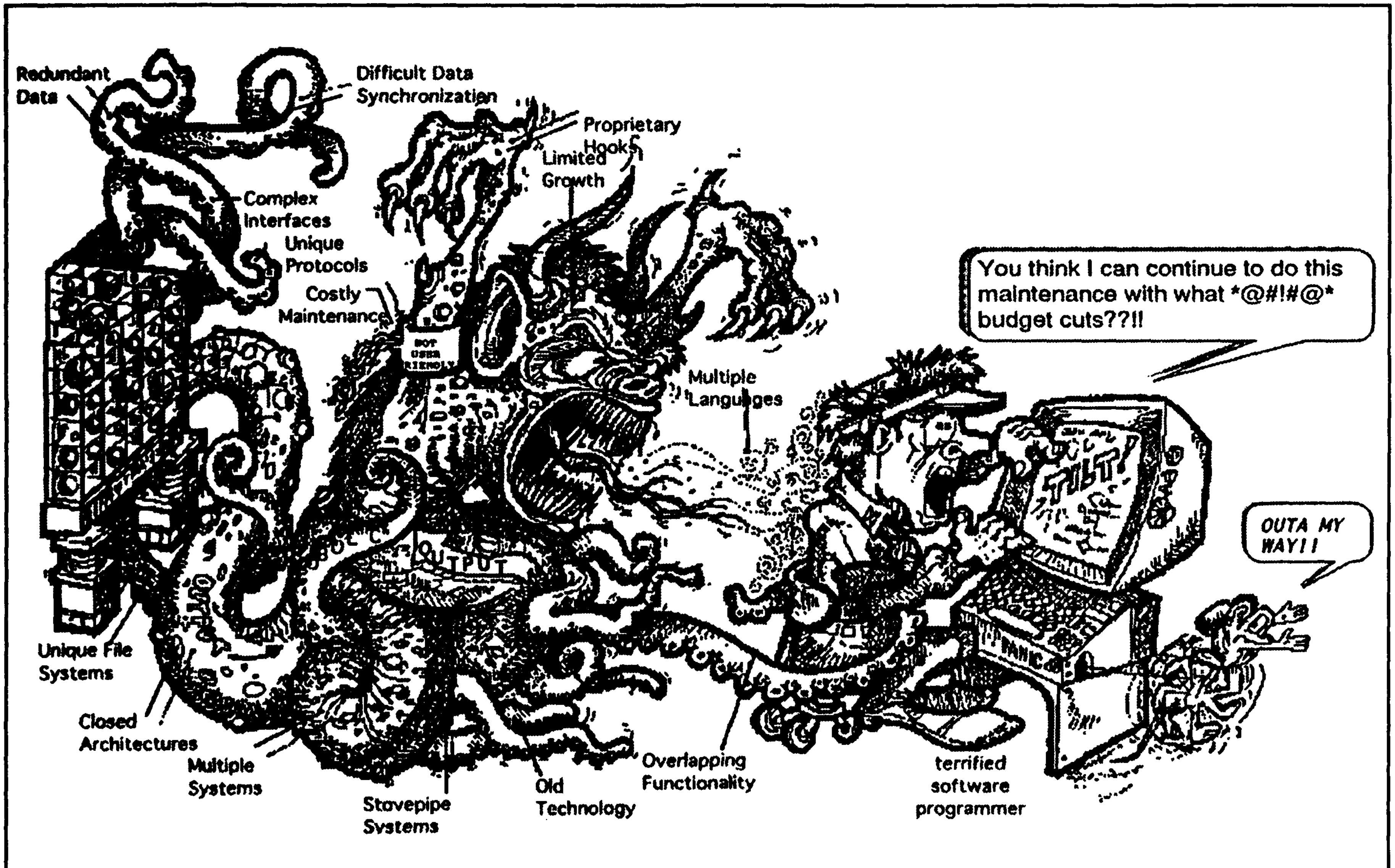


Chart 3 - 6/23/93

Program Manager Challenge

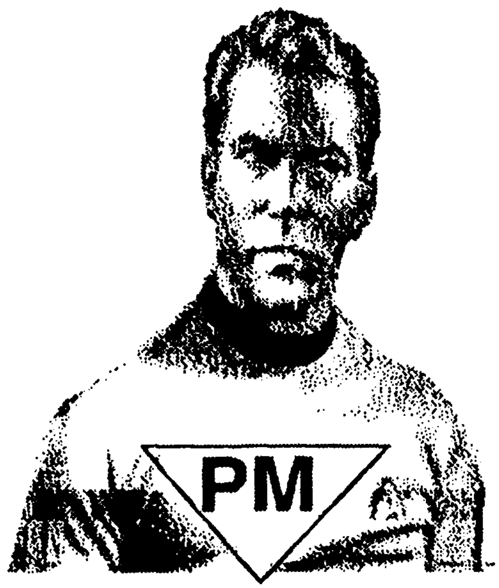
Cost ?

Schedule ?

Performance/ Functionality ?

Evolvability ?

Reliability ?



? Contractor Capabilities

? Form/Fit/Function

? System Engineering

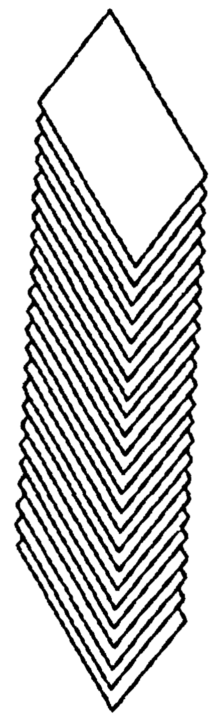
? Compiler Vendors

? DoD Acquistion Policy

What is a Million LOC?

50 lines/page → 20,000 pages
300 pages/inch → 66 inches
5 ft. 6 inches high!

- Requirements
- Software Development Plan
- Software Requirement Specification
- Software Design Description
- Database Description
- Computer Program Configuration Items
- Software Development Folders
- Test plans/procedures
- Formal Qualification Test
- Other non-operational SW



Operational Code

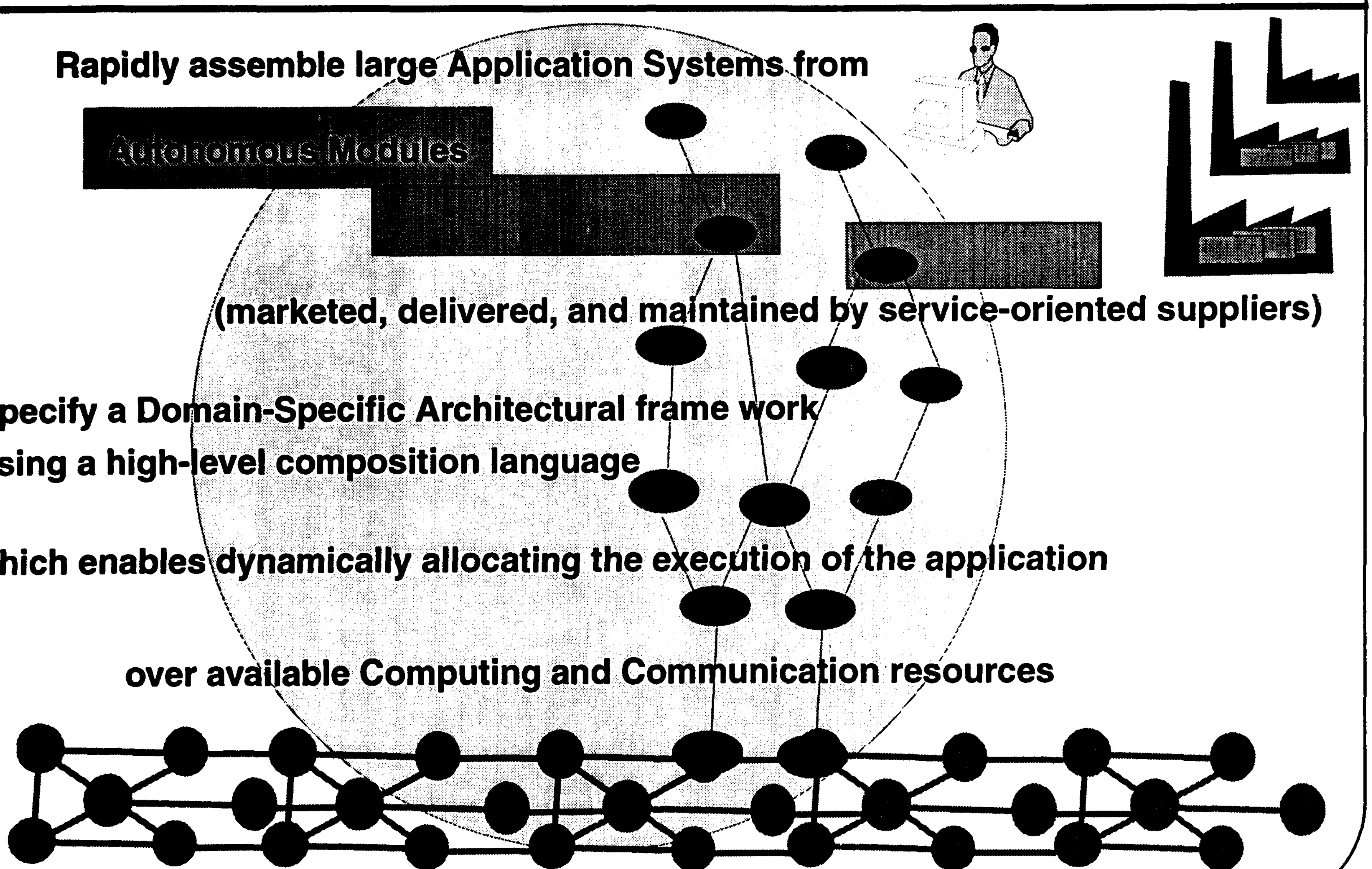
Outline/Purpose

ARPA

- Review Key software engineering challenges
- Define Vision for future software development
- Highlight Current Software Engineering Strategy and Activities
- Summary/Opportunities for Industry

Desired Capability

Rapidly assemble large Application Systems from



(marketed, delivered, and maintained by service-oriented suppliers)

Specify a Domain-Specific Architectural frame work
using a high-level composition language

which enables dynamically allocating the execution of the application

over available Computing and Communication resources

Support a Paradigm Shift

cottage industry to service industry

	Today:	***Future:***	***Needed Support to move forward:***
characteristic	A SW system owns all its own resources and its owner is responsible for all its maintenance	A SW system obtains services from autonomous modules and the supplier performs and sells maintenance	Many innovative vendors who can provide • trust worthy services that perform • valuable functions and can • interface with others.
	Interfaces are informal and require much filler	Interfaces follow standards (generic or domain-specific)	
architecture	Each new system is an inventive new design, but useful features are easily forgotten or awkward. The purchaser is locked in..	Each new system is a version of others in its domain, the latest modules are obtained from the suppliers, who compete on quality.	Consensus in • domain architectures • their description • interface descriptions • composition languages

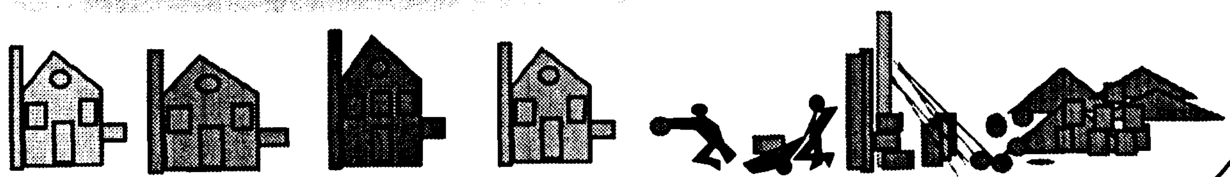


Chart 8 - 6/23/93

Software Development Capabilities Vision

ARPA

	Today	3-5 yrs	7-10 yrs
Needs Determination	• "Boxology" • Incomplete/Inconsistent	• "Scenario based" • Use prototypes	• Architecture based • Tradeoff costs/benefits
How Designed How Built	• Box by box • Line by line • Each new system is an invention	• Initial architecture • Rapid incremental component integration • "Product line" approach	• System Composition Capabilities • Very High Level, Domain Specific Languages • Components marketed, delivered, maintained by service oriented suppliers • Formal product line approach
Evolution Process	• Tear up / redo • Informal/poorly defined interfaces	• Incremental integration • Interface constrained (evolution within static interfaces)	• "Design record": seamless evolution from prototyping thru product life cycle
Who does it	• Highly trained SW specialists • Developer isolation	• Well integrated teams of engineers • User/developer interaction	• User modification and tailoring
		• ARPA SW builders need to get here • Some SISTO R&D focused here	• SISTO R&D focused here

Outline/Purpose

- Review Key software engineering challenges
- Define Vision for future software development
- Highlight Current Software Engineering Strategy and Activities
- Summary/Opportunities for Industry

Qualities, Technical Factors and Thrusts

Qualities

Evolvable
Predictable
Reliable
Cost Effective
Valuable

Technical Factors

Computational Models
Language Understanding
Deductive Methods
Component Specification Languages
Component Analysis & Verification Systems
Component Synthesis Systems
Heterogeneous Language Interoperability
Prototyping Technology
Architecture Theory
Architecture Definition Languages
Architecture Conventionalization
Architecture Analysis & Verification
SEE (Process Support)
SEE (Artifact Transformation)
SEE (Data Integration)
SEE (Control Integration)
SEE (Object Interoperability)
Software Process and Measurement
Execution Analysis
Reuse Technology
Product Line Approaches
Demonstration & Evaluation
Technology Transition
Component Generator/VHLL

Thrusts

- Component-based design/implementation (Megaprogramming)
- High-Assurance
- Development/Evolution process
- Tools & Environments (Tool Infrastructure)
- Technology Transition

Software Engineering

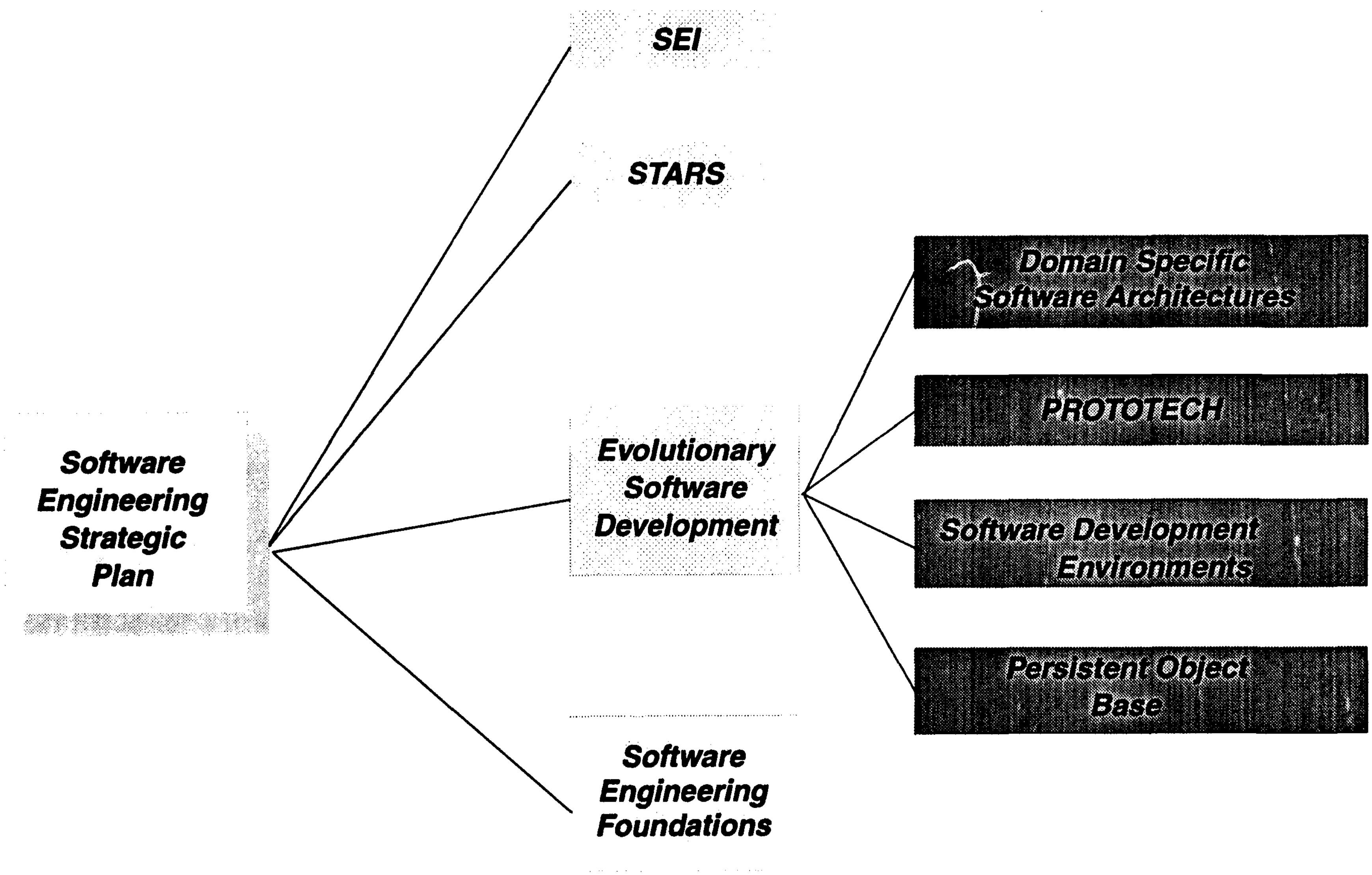


Chart 12 - 6/23/93

Current Program Emphasis Areas

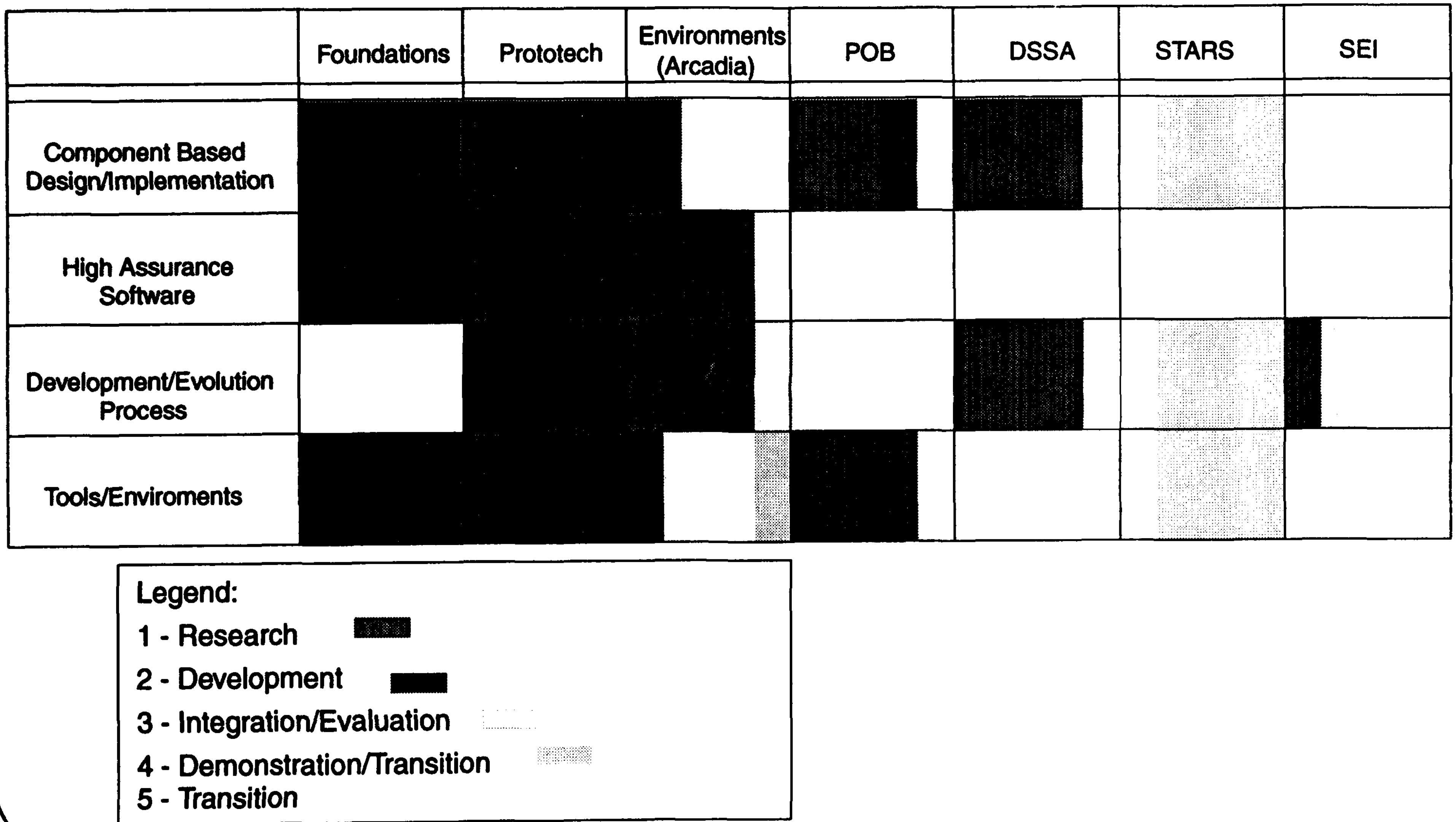
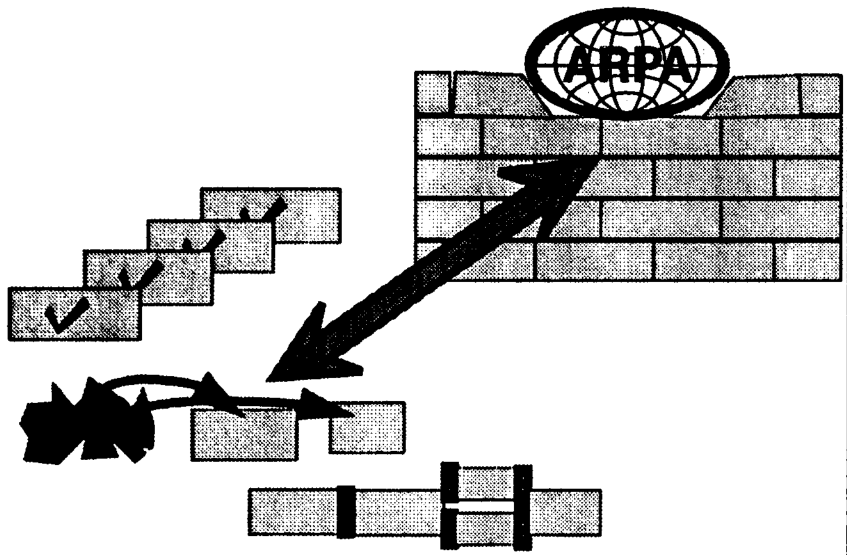


Chart 13 - 6/23/93

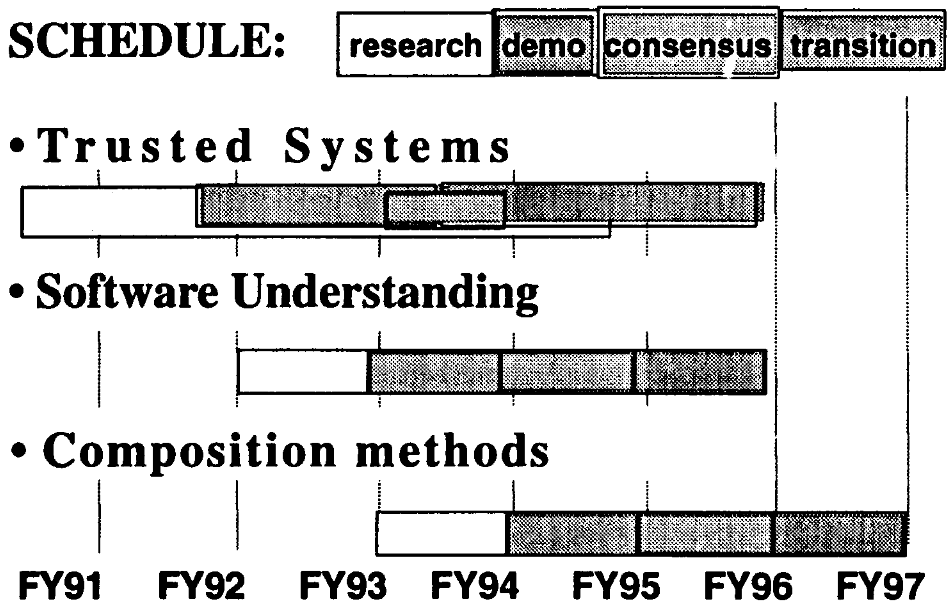
Software Engineering Foundations



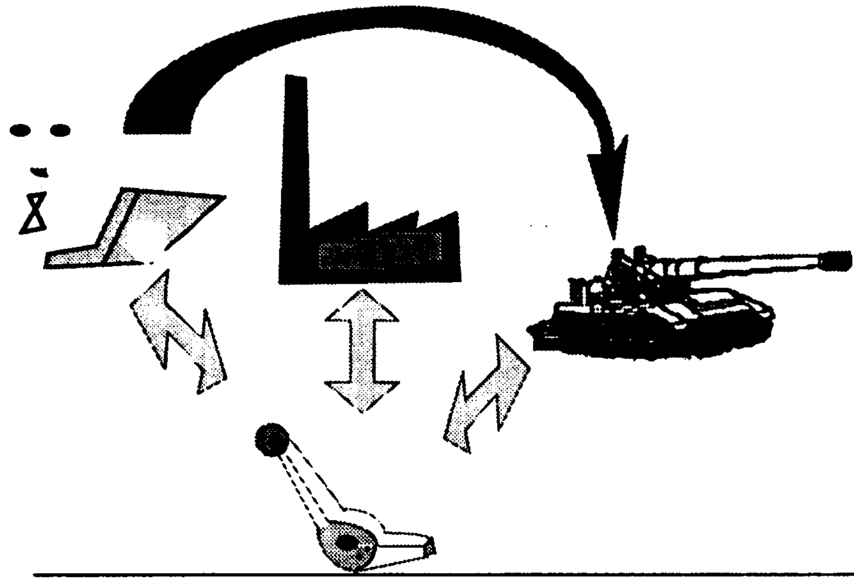
KEY IDEAS:
Verification of well-formed modules
Extraction of proven algorithms from extant, useful software
Extraction of domain architectures from extant, useful software systems
Establish interface formalisms
Developement of generic languages to express domain-specific architectures & application module composition

IMPACT:
Software systems which can be
1. Rapidly composed
2. Economically evolved
3. Share COTS and DoD components
4. Interact with a dual-use industrial base

SCHEDULE:



Persistent Object Base



KEY IDEAS:

Increase Consistency of Engineered Products by storing data and interpreting methods

Assure Scalability and Longevity via an Open architecture

Object and Application Interoperability

Gain acceptability by
1. Building and diseminating a working prototype
2. Working with standards organizations that represent vendors and users

IMPACT:

Industry support for Common Query Language

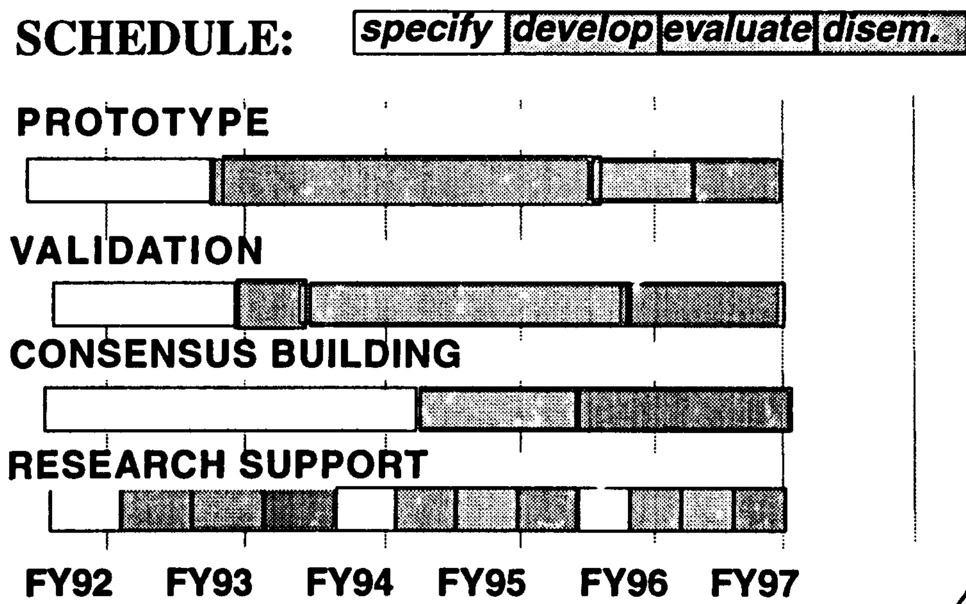
OMG adoption of OO-model based on POB proposals

Availability of alpha release triggers demand

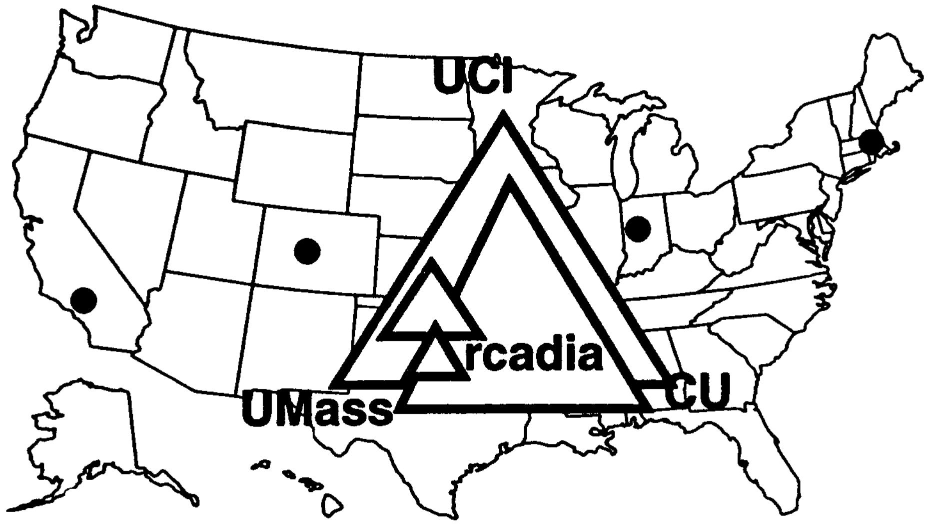
Disseminition for PDES and CALS when ready

Dual use technology

SCHEDULE:



Software Environments
(Arcadia)



Key Ideas

Basic Research and Exploratory Development to

- Develop Infrastructure to support heterogenous systems
- Integrate process concerns into software support environments
- High assurance software - dependency analysis and concurrency analysis

Impact

- Generic language processing tools based on common internal forms (Aflex, Ayacc, IRIS, APPL/A, etc.)
- Environment architecture and interoperability mechanisms
- Process Modeling, Programming and Execution
- Object Management
- Measurement and empirical evaluation
- User Interface

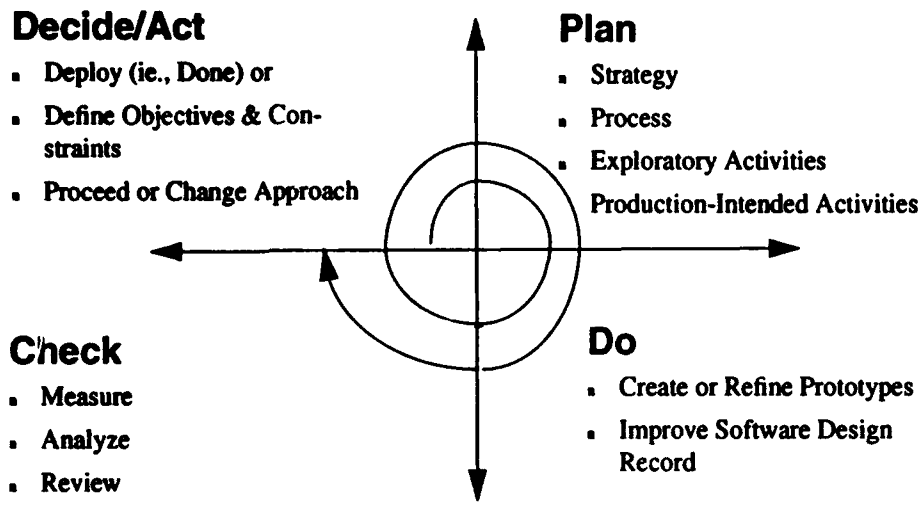
Schedule

FY 94

- Componentize capabilities
- Integrate components with other SEE's
- Use/Evaluation

Prototyping Technology (ProtoTech)

A Prototyping Cycle



Key Ideas

Basic research and exploratory development for doing software concept demonstrations and feasibility experiments so as to ensure predictable rapid transformation of prototypes into operational systems.

- Language support for evolutionary development of software components
- Specification techniques for complex software architectures
- Support for software systems with components written in multiple programming languages
- Experimental tools to support refinement of software prototypes into production quality systems

Impact

- Potential means to achieve early validation of systems both during development and as they evolve through the life cycle.
- Decreased risk in requirements formulation and design
- More efficient evolution of systems over their life cycle, resulting in enhanced overall system effectiveness and reduced costs.

Schedule

FY93
Development of prototyping languages
Demonstration candidates evaluated and selected
Preliminary architecture description language (ADL)

FY94
Prototyping language available for general use
Architecture description language (ADL) used in DSSA experiment

FY95 (planned)
Integrate current ProtoTech with other technologies and enviroments
Maturation, Commercialization, and Transition

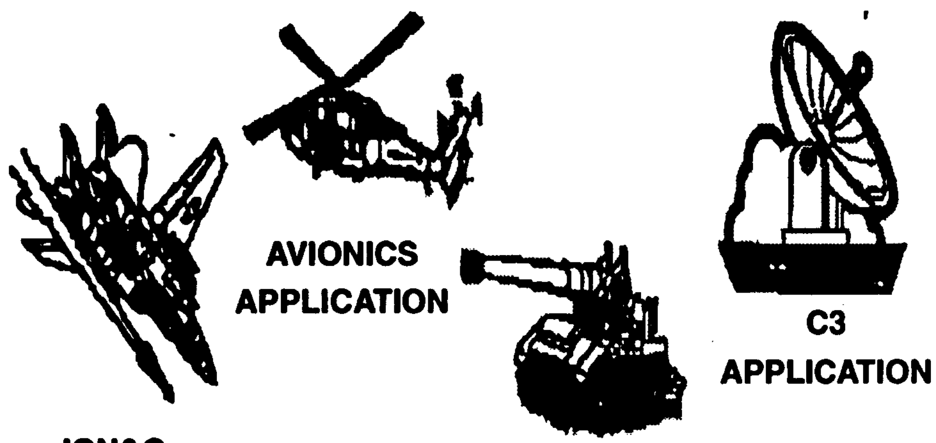
ProtoTech
Team Focus Areas

ARPA

Teams	Focus	Demo Activity	Theme
Duke/UNC/Kestrel	Parallel Computation (Proteus)	3D Molecular Dynamic Simulations	1 [2]
Honeywell/U of Maryland	Interconnection Technology, Graphical Modeling Tools/MILs (Polylith) + ADLs(ArchEd)	Apply to GN&C DSSA Interconnection Tech, Graphical Modeling Tools and Infrastructure	2, 3
Intermetrics/Yale/ ISI/SOI	Functional Languages (Haskell), Language Interoperability (ELIF) with Ada9X, CLISP, C++	Navy C2 re-engineering into Ada 9X including Artifacts System for GNU Ada9X	1, 3, 4
NYU/Raytheon	Migration to Ada (Griffin)	Raytheon Applications in: Track Mgmt; Radar Tracking; Military Airspace Mgmt System	1, 2
Stanford/TRW	Performance Analyses (Rapide)	IBM ADAGE Avionics; Secure Systems; Industry Reference Architectures	1. 2
Colorado	Interoperability of Heterogeneous Systems	Integration of Arcadia/Prototech/POB/I3 Tools	3, 4
Illinois	Schedulability Theory (PERTS)	Validate Real-Time Constraints for: Avionics and Flight Management, Air-Traffic Control, etc...	4 [3]
Teknowledge	Open Architecture Infrastructure, Tools, Application Experimentation	DSSA/Vehicle Management Systems	3, 4

[ ] Secondary Theme

Domain Specific Software Architecture



New Ideas

- A DSSA is a specification for assemblage of software components:
  - specialized for a particular class of tasks (domain)
  - generalized for effective use across that domain
  - composed in a standardized structure (topology)
  - effective for building successful applications
- Architecture Driven Development Process
- Component-Based Development
- Automated Application Generation

Impact

- Significant (order of magnitude) reduction in software development cost and schedule
- Reduced risk and improved system quality and reliability as systems are constructed from proven architectures and proven parts
- Significant reduction in software maintenance costs, due to lower error rate, improved component quality, and single-point maintenance of common parts.

Schedule

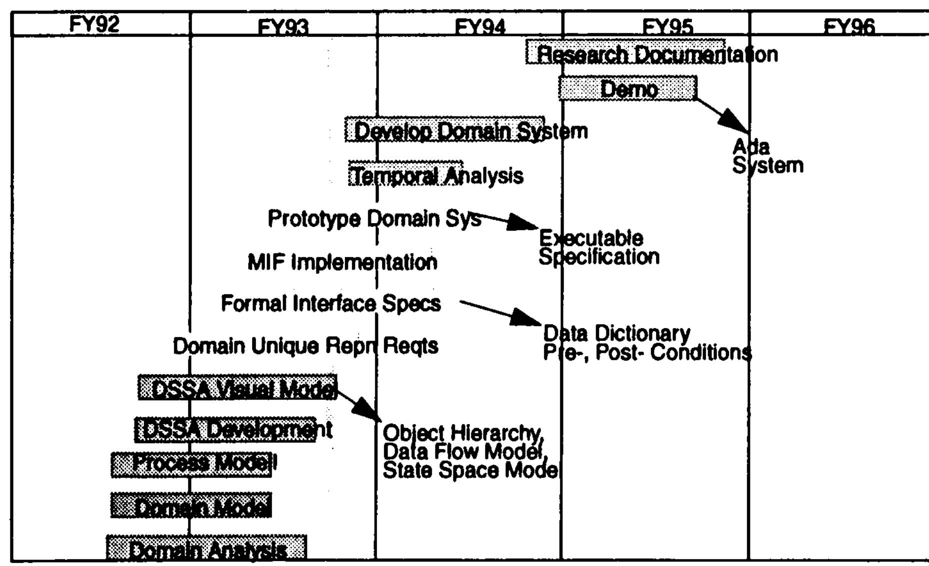
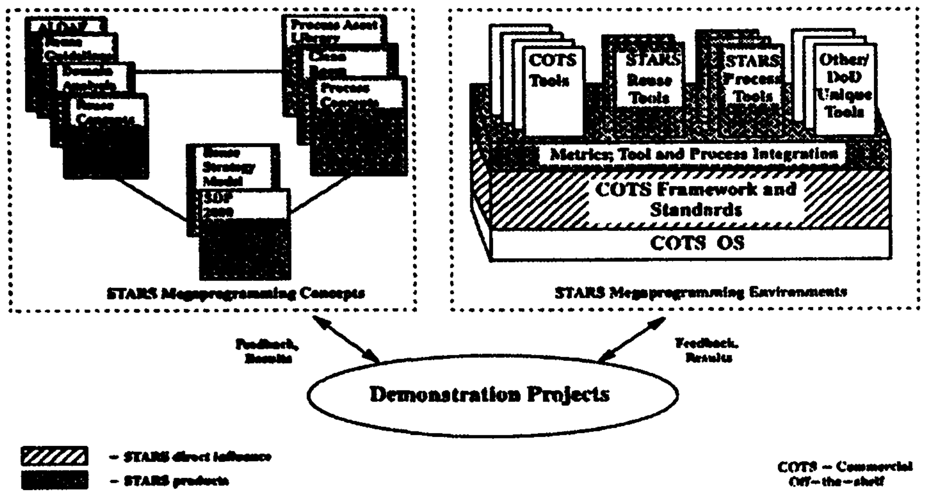


Chart 19 - 6/23/93

Software Technology for Adaptable, Reliable Systems (STARS)



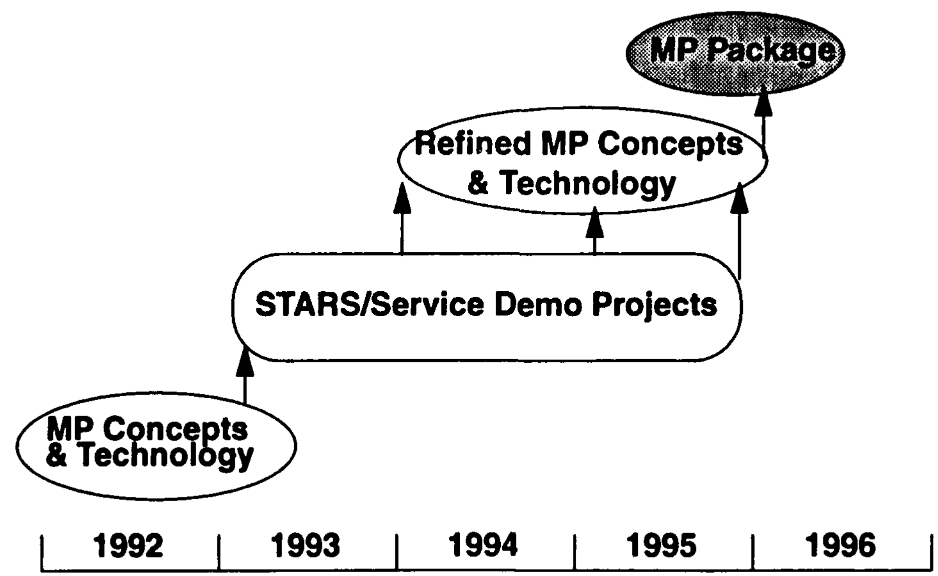
Key Ideas

- Domain Specific Reuse
- Process Driven Development
- Integrated Software Environments
- Active Technology Transition
- Demonstration Programs - Real service applications
  - Army: Improved Guardrail V (Electronic Warfare)
  - Navy: T34C Flight Instrument Trainer
  - Air Force: Space/Command Control

Impact

- Domain Analysis Technology
- "Product Line" development approach
- Framework based Tool Integration Technology
- Cleanroom Software development
- Commercialization
- Measurement/Metrics technology
- Reuse libraries
- Standards

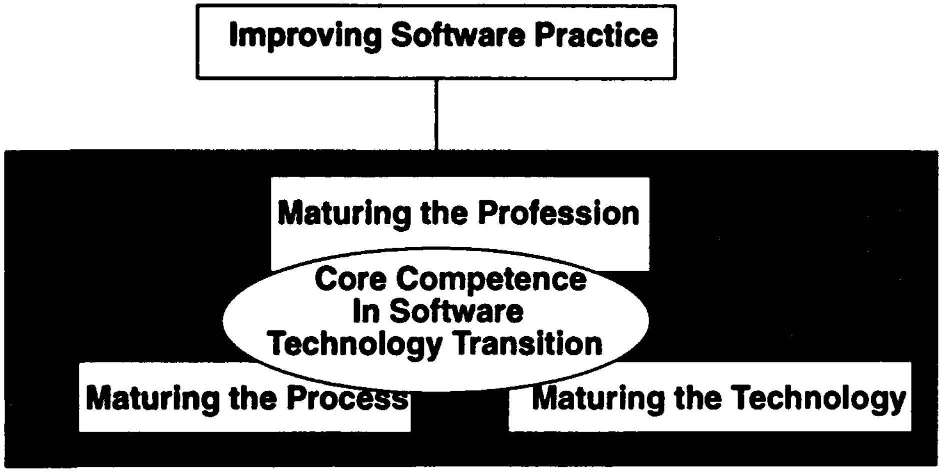
Schedule



Army STARS Demo Project Goals

CAPABILITY	CURRENT BASELINE	DEMO GOAL	ORGANIZATION VISION
Software Process	Project-Specific PDSS Process	• Value-Added PDSS Process Defined for Project • Reuse and Reengineering Based	Standard/Defined/Tailorable Process for SED
Software Reuse	Opportunistic	Strategic: • Reusable Assets Based on Domain Model and Architecture • Domain Library • Reuse Within Domain	Strategic: • Domain Managers • Product Line Approach
Software Architecture	• System - Specific • Evolution Limited	• Domain - Specific • Evolution Enabled	• Domain - Specific • Evolution Enabled
Software Engineering Enviroment (SEE)	Project Specific Support	• Tailored to Project • Adaptable to Other Projects • Control Integration Focus	• Standard Framework • Independent Tool Integration • Control, presentation, & Data Integration
IGRV Software Baseline	FORTRAN / Assembly (380K LOC)	• Restructured Against System Architecture Derived in part from Domain Architecture • Reusable Components in Ada	
Technology Transition	Opportunistic	• Project Process Defined as Model for SED • STARS Tech. Transitioned	• Standard Process • STARS Technology Institutionalized • Tech. Pipeline Established

Software Engineering Institute



Improving software practice by maturing the profession, the process and the technology of software engineering through a core competence in software technology transition

New Ideas

- Software Process: a defined, measured, and managed process for developing software
- Risk: a systematic approach for identifying, analyzing, and managing technical uncertainty and its impact on software development
- Methods and Tools: domain models and architectures supported by methods and tools for disciplined engineering of software systems
- Real-Time Distributed Systems: quantitative methods for defining, analyzing and evaluating timing, performance, reliability and other quality attributes of software systems
- Software Engineering Education: products that improve the software engineering profession by improving software engineering education

Impact

- A continuous software process improvement program is adopted by all major software-producing organizations in the defense-contractor community
- A system is in place that allows quantification and tracking of effectiveness in reducing risk in software intensive systems
- SEI is acknowledged as a leader in providing an integrated set of model-based processes, methods, and tools for disciplined engineering of software systems
- Fostered agreement on quantitative design methods for achieving specified quality attributes of software systems supported by handbooks (e.g. handbook for design of real-time systems).
- Ten to fifteen universities will have been assisted in establishing graduate programs in software engineering

Schedule

FY 94

- Engineering Models Training Course (Initial offering)
- Updated Software Process Assessment (SPA) and Software Capability Evaluation (SCE)
- Structured Model Guidebook for Real-time Air Vehicle Simulators
- Risk Identification Training Course

FY 95

- Graduate Programs in Software Engineering
- Model-based Software Engineering Guidebook

FY 96

- CMM Validated Through Impact Study
- CMM Updated for Small Organizations

FY 97

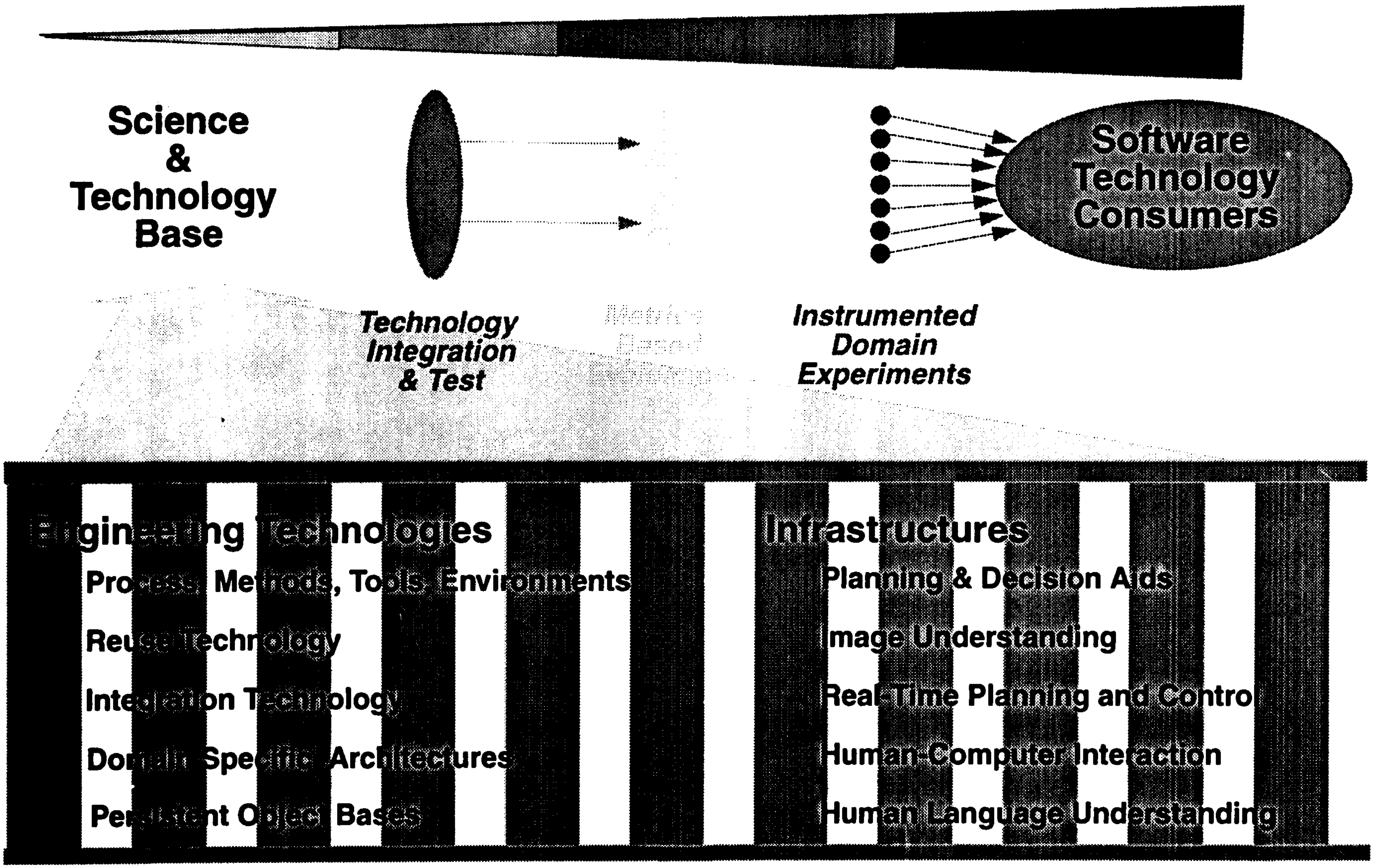
- CMM Version 2.0

Key Software Concepts

ARPA

- Systems will continuously evolve over the life cycle
- Rapid/cost effective migration from concept to operational use
- Systems can be rapidly constructed from standard architectures and a repository of components (designs, code, manual, ...) (megaprogramming)
- Quest for commonality within and across domains to allow reuse and potential for very high level (domain specific) languages
- A disciplined process
- Need to measure and assess process, products, and techniques

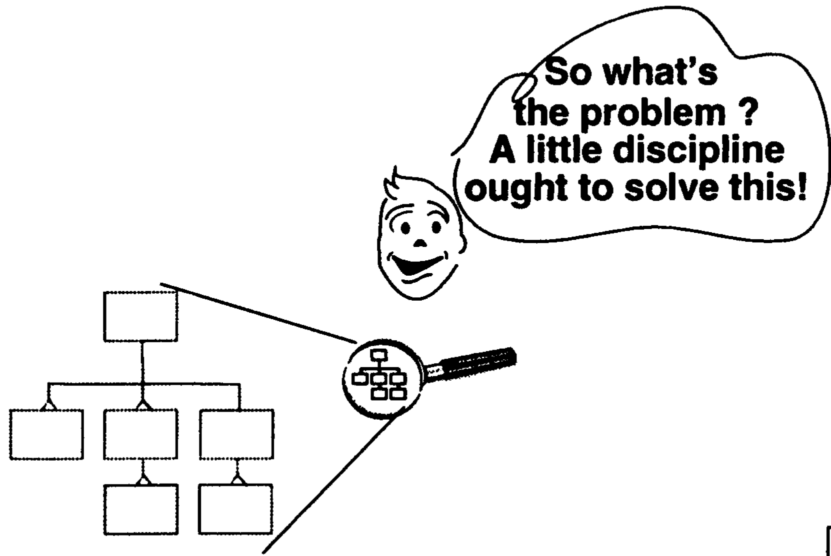
Software Technology Investment Strategy



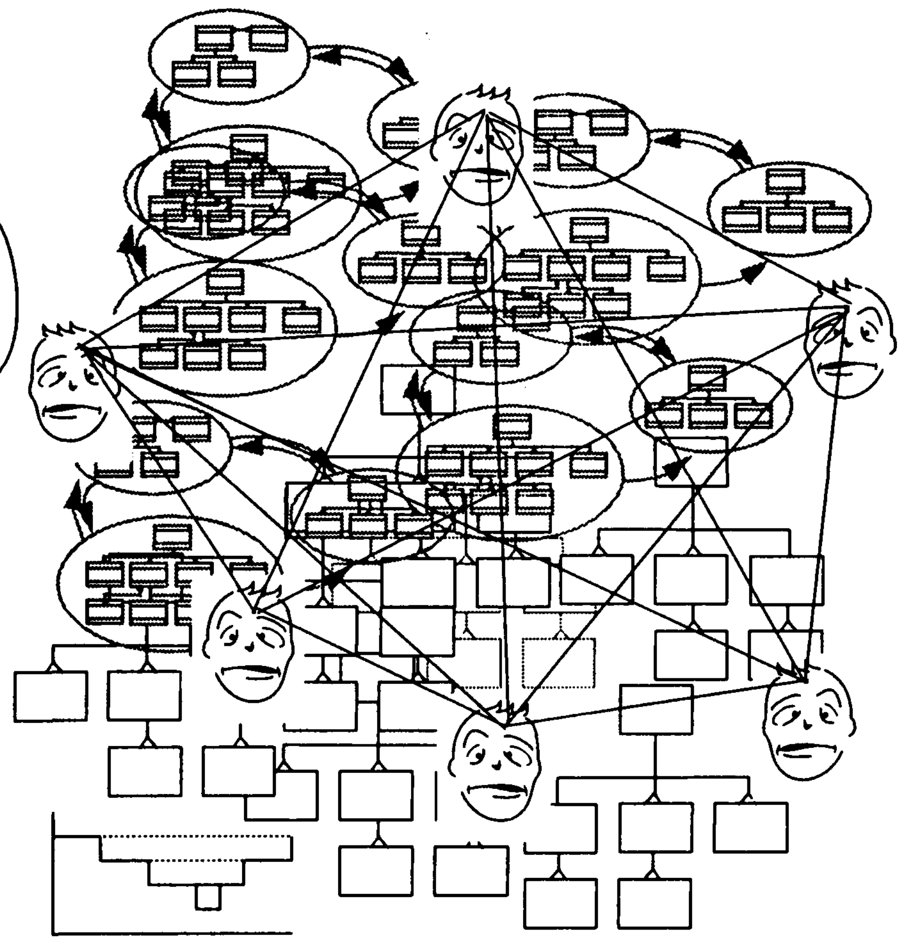
ARPA

Backup Slides

Software Developer's Failure to Communicate



Management's Perceived Complexity of the Software Development Problem



Software Developers Perceived Complexity of the Software Development Problem

Software Qualities and Thrust Areas

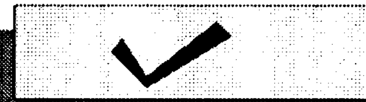
	Component Based Design/ Implementation	High Assurance Software	Development/ Evolution Process	Tools/ Environments
Evolvable	X			X
Predictable	X	X	X	X
Reliable	X	X		X
Cost Effective	X		X	X

INITIATIVES

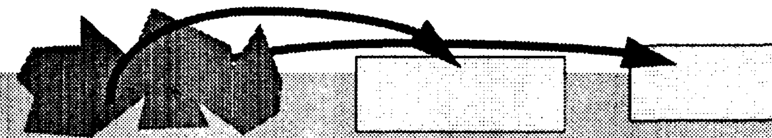
Trusted Systems:

Validating that Software Modules meet Specifications

Testing can only show Errors, not Correctness



Software Understanding:

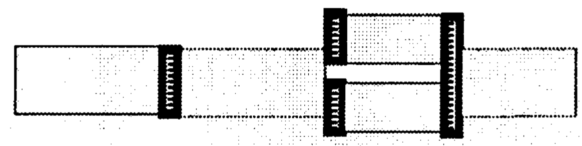


Extract knowledge from old Software to new Modules and Architecture

Software contains Meaning and Implementation information,

Only the Meaning must be retained

Module Composition:



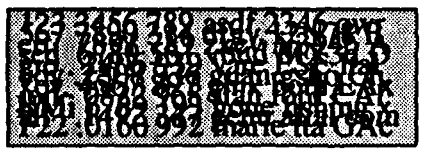
Principles, Interfaces, and Methods for Making SW Reusable

Reuse via Megaprogramming is shown effective by example,

its dissemination requires a proven scientific infrastructure

Persistent Object Bases

- ***What is a* Persistent Object Base (POB)*?***
  - A sharable collection of structured data and methods to interpret those data,
    - a resource for collaboration in a particular domain,
    - a foundation for recording product standards and instances
    - a means for recording progress in design and planning processes
- ***Why do we need a* POB?**
  - Object Technology provides a meaningful aggregation of base information:
    - Relational databases only store detailed facts:



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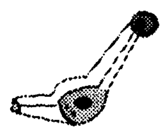
  - Objects aggregate values and computations:



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= MaxVertExtension
= Picture
(computed)

  - Less work for the applications that use the data
  - Fewer errors due to misinterpretation, I.e., more consistency
  - More flexibility to change contents of objects, while retaining their functionality

Software Environments
Arcadia

Technical Objectives:

- Provide open, extensible, scalable, integrated support environment
- Develop the infrastructure required to support a heterogeneous system
- Integrate process concerns into support environment
- Integrate tools to support development of high assurance software into environment

Software Environments
Arcadia

Major Efforts/Accomplishments:

Environment architecture and interoperability mechanisms
- "Software Bus" providing flexible control integration
- Intermediate representations and tools to support language interoperability
- Demonstration of mechanisms for supporting interoperability across heterogeneous databases

Process Modeling, Programming, and Execution
- Developed language to describe software process
- Experimentally applied language to several processes
- Integrated language with support environment

Object Management
- Defined requirements for types and methods (working with POB)
- Developed capabilities for linking heterogeneous systems

Software Environments
Arcadia

Major Efforts/Accomplishments:

User Interface

- Demonstrated support of heterogeneity with system that supports applications in multiple languages, supports concurrent control of interface with coordinated update of multiple graphical and of interface with coordinated update of multiple graphical and textual views

Measurement and empirical evaluation

- Provided "active" measurement capability -- triggered by environment
- Define metrics and collection process with Scripts
- Support classification to identify predictive metrics

Software Environments
Arcadia

Major Efforts/Accomplishments (cont.):

Testing (Dynamic Analysis)

- Several tools to support dependency analysis (required for test data generation, assessment of "ripple effects" from program modification, test data generation, safety analysis)
- Tools for concurrency analyses
- Analysis tool infrastructure based on flexible, generic components that share information (demonstrating support for heterogeneity)
- Definition of testing process and provision of capabilities to manage and execute test classes

Software Environments
Arcadia

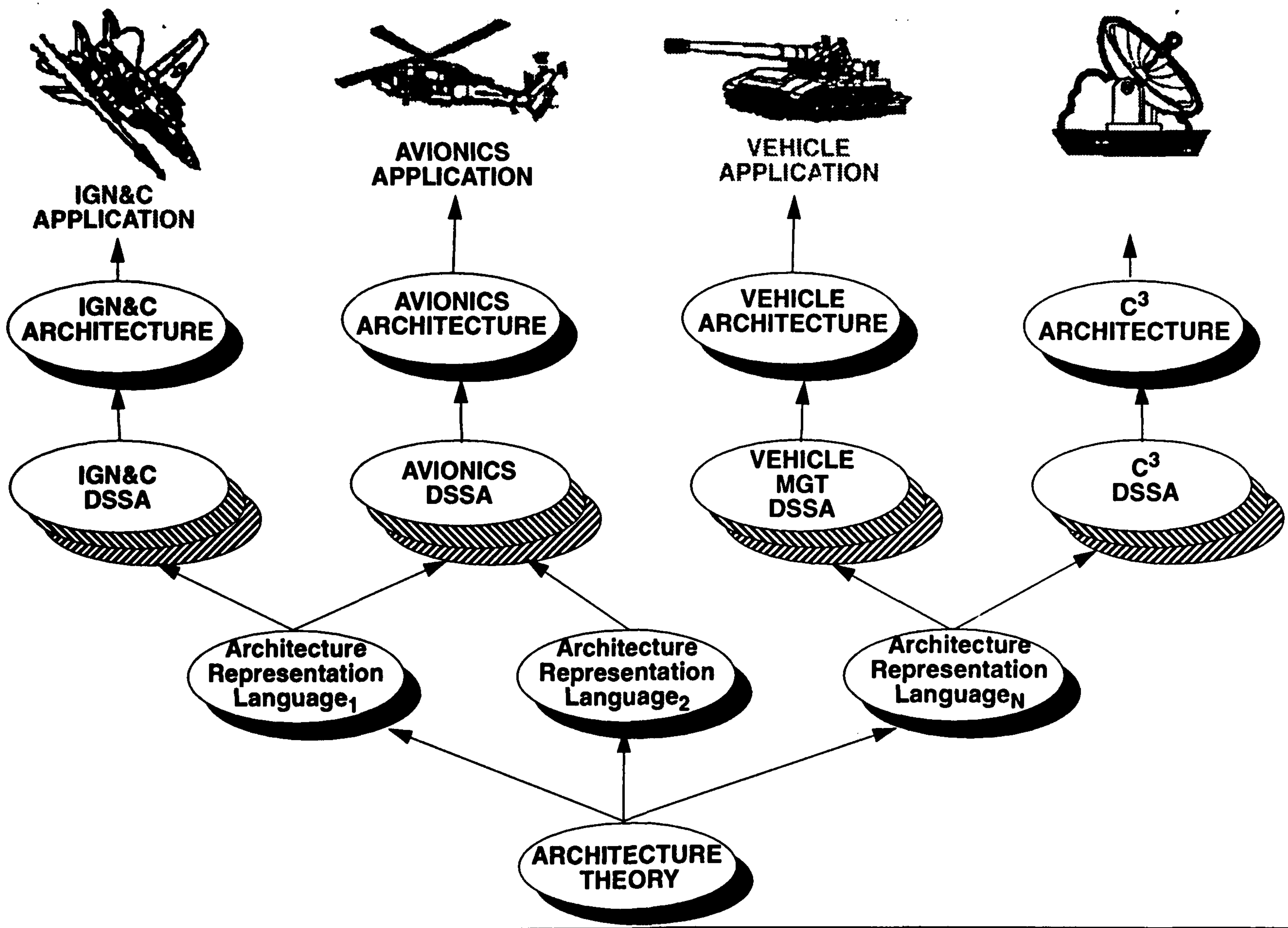
Plans:

Project scheduled for termination March 1994.

This team (UC, Irvine; UMass, Amherst; UC, Boulder; Purdue) could play major role in shaping computing environments of future. Specific areas for major contribution include:

- Definition of Software Bus Standard for research community
- Acceleration of convergence on object manager requirements/ interfaces
- Experimental scale-up and evaluation of existing concurrency analysis tools

DSSA
Program Approach



Software Engineering Institute

Technical Objectives:

- Facilitate transition of technology to improve the State-of-Practice in Software engineering

Major Efforts/accomplishments:

- Developed curriculum for MS in SE
- Popularized need for process improvement and provided measuring instruments (capability maturity model)
- Began development of risk taxonomy
- Supported maturation of Rate Monotonic Analysis and Environment infrastructure frameworks

Plans:

- Continue Software Engineering Education activities
- Prototype approaches to process improvement and process for risk management
- Develop "engineering maturity model"
- Prototype architectural models addressing reliability and distribution

III-E INTELLIGENT SYSTEMS

DR. EDWARD W. THOMPSON

Intelligent Systems

ARPA Symposium
June 23, 1993

Dr. Edward Thompson
Director, Software and Intelligent Systems Technology Office
Advanced Research Projects Agency

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TALKING PAPER TO ACCOMPANY INTELLIGENT SYSTEMS PRESENTATION

- this presentation will be given at the Advanced Research Projects Agency (ARPA) Symposium at the Naval War College, Newport RI on June 23, 1993.

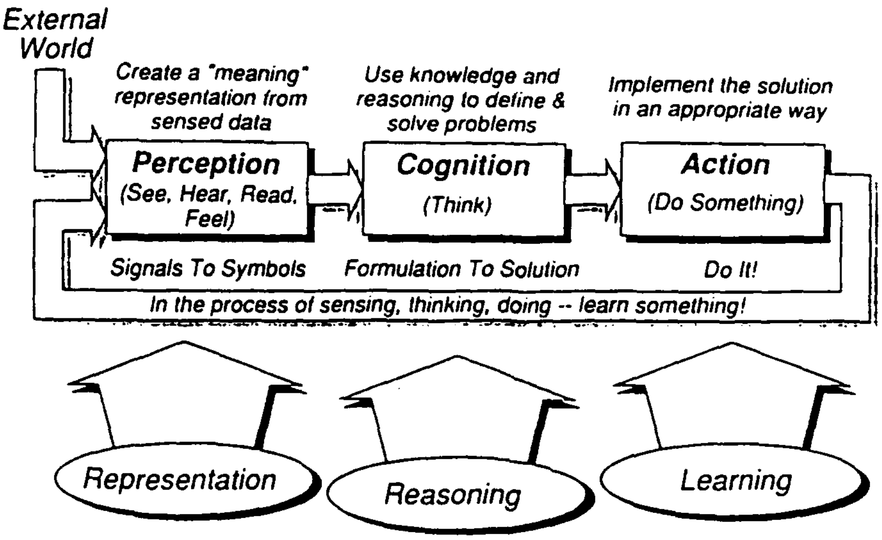
- this presentation is unclassified, unrestricted access

Outline

- What is an intelligent system?
- What is the SISTO strategy?
- What is the current program emphasis?
- What help do we need from you?
- Summary

the purpose of the presentation is to give the ARPA Software and Intelligent Systems Technology Office's perspective on intelligent systems, strategies for the development and transition of the enabling technology to build intelligent systems, and the background of current science and technology programs in machine intelligence

What Is An Intelligent System?



Enabling technology based on machine intelligence research

ARPA IS 003-93

- an intelligent system involves one or more of the following three capabilities (perception, cognition, action). The overall objective is to understand how to develop computer systems that can function in human-like (or other animal-like) ways in these areas. In general, the key enabling technologies are knowledge representation, reasoning methods, and learning methods.

- perception is more than simple signal measurement. It involves interpretation, fusion, uncertain reasoning -- all with the goal of creating a "meaning representation" or understanding of the sensed data. the sensed data may include speech, imagery, text, and/or other sensor data (temperature, infra-red imagery, etc.). often the "meaning representation" is symbolic - which facilitates its processing by other intelligent system components. early applications dealt with intelligent front ends to databases, but the work has now progressed (for example, real-time, speaker independent, 20,000 word vocabulary speech systems)

- cognition implies thinking. thinking means formulating a symbolic representation of a problem, and then applying reasoning process to solve the problem. a problem might involve diagnosis, design, planning, monitoring, projection (or anticipation of future events). early work dealt with expert systems.

- action means to carry out explicit operations (via actuators or communication) to attempt to modify the world.

Three Classes Of Intelligent Systems

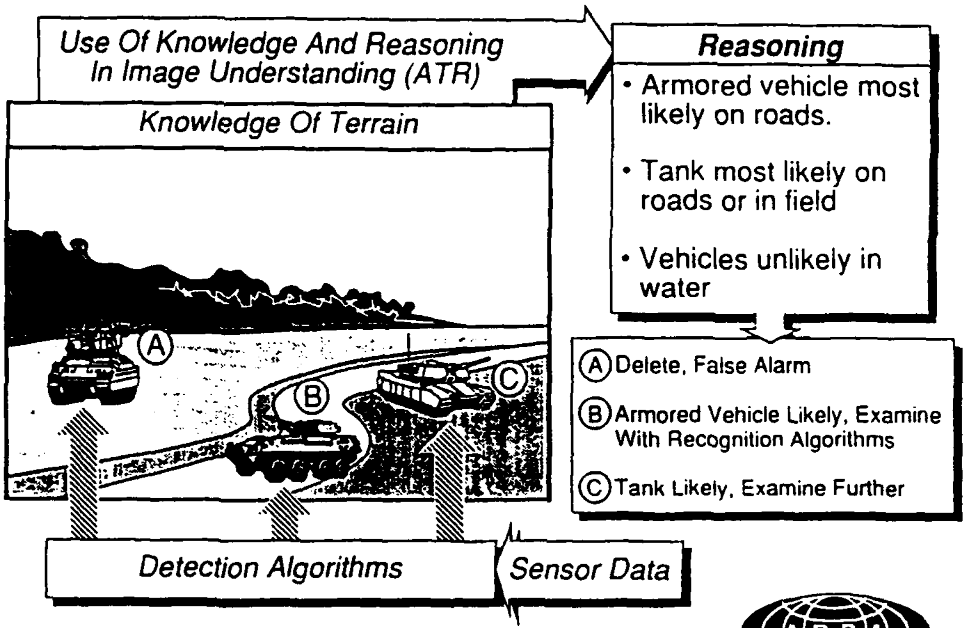
- Advisory Systems
  - Associate Systems
    - Autonomous Systems

These Systems Can Be Distinguished Based On:
• Degree Of Authority & Autonomy • Degree And Type Of Cooperation • Type Of Assistance Given • Degree Of Naturalistic Intelligence In Communication & Cooperation • Richness Of Sensors And Actuators

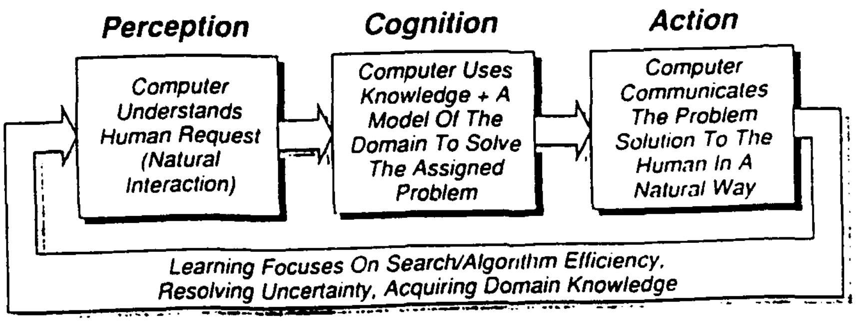
ARPA IS 005-93

- there are three classes of intelligent systems: advisory systems, associate systems, and autonomous systems. The following viewgraphs will define and illustrate each class.

Power Comes From Knowledge And Reasoning



Advisory System



Examples:

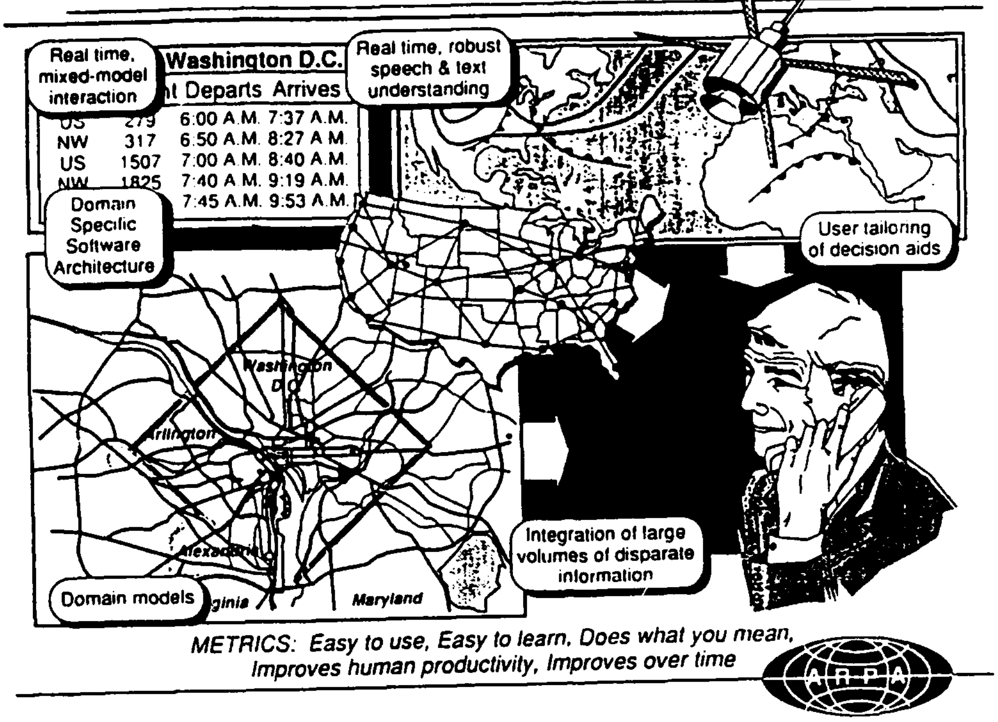
- **On-Line Air Travel Planning**
  - Anybody Can Talk To The Computer And Get Flight Information
- **DART**
  - Military Planner Can Visualize Plan, Recognize Errors, Save Days In Planning

ARPA IS 006-93

DISTINGUISHING CHARACTERISTICS:
human specifies task domain human in charge value added by ease of use, increased human-computer bandwidth requires high performance speech, text, image understanding

- one type of intelligent system is the advisory systems.
the early work concentrated on intelligent database frontends.
now the goal is to enable some sort of labor saving, decision support via naturalistic interaction between man and machine. key features that distinguish an advice giving system from other intelligent systems is the fact that this system tasks are defined apriori by a human and that a human is in charge.

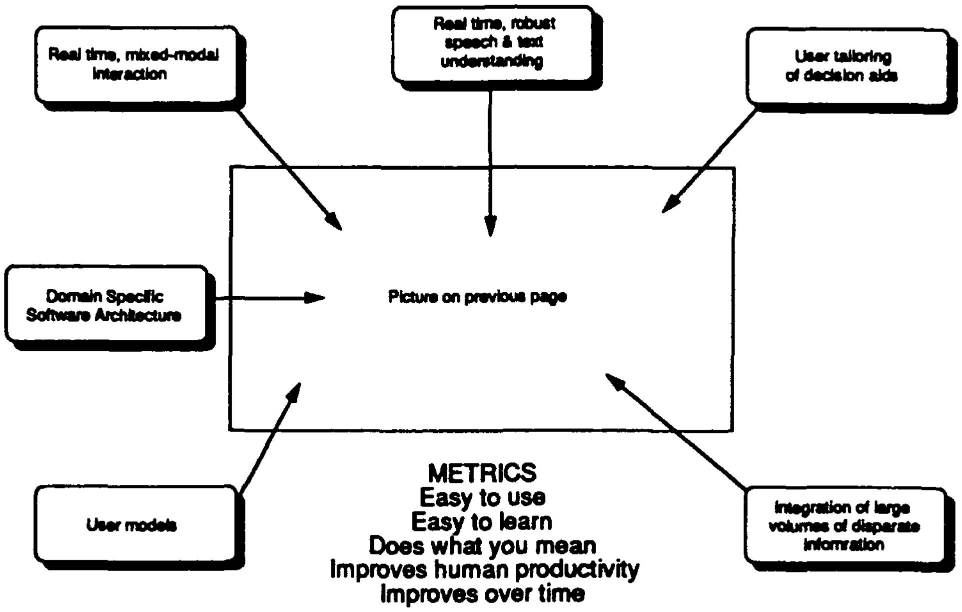
On-Line Trip Planning



ARPA IS 007-93

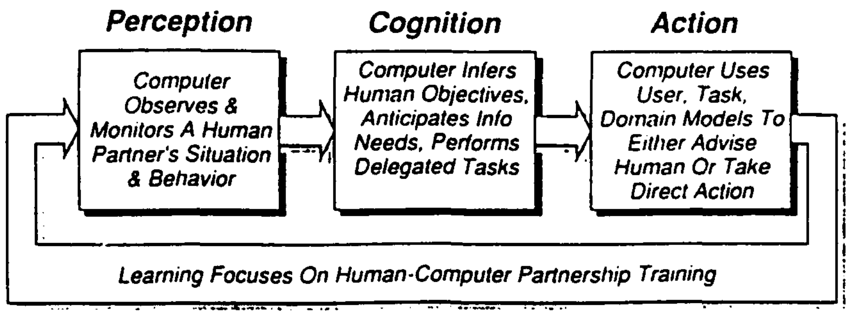
- an example of an advisory system is the use of high performance speech understanding techniques to support on-line trip planning - that is, interaction with an airline information database. This task domain has been used for the past three years by the ARPA Human Language Technology community to develop the underlying speech understanding technology. The above picture suggests the speaker independent, robust performance that is now possible.

On-Line Trip Planning



- in order to produce effective, low cost advisory systems, several additional research issues need to be explored. These include mixed-modal interaction (integration of speech and gestures), efficient implementations of speech and text processing algorithms, integrated decision aids that ordinary people can tailor and evolve, models of users ("do what I mean, not what I say"), new techniques to integrate large amounts of data, and a domain specific software architecture for advisory systems.

Associate Systems



Examples:

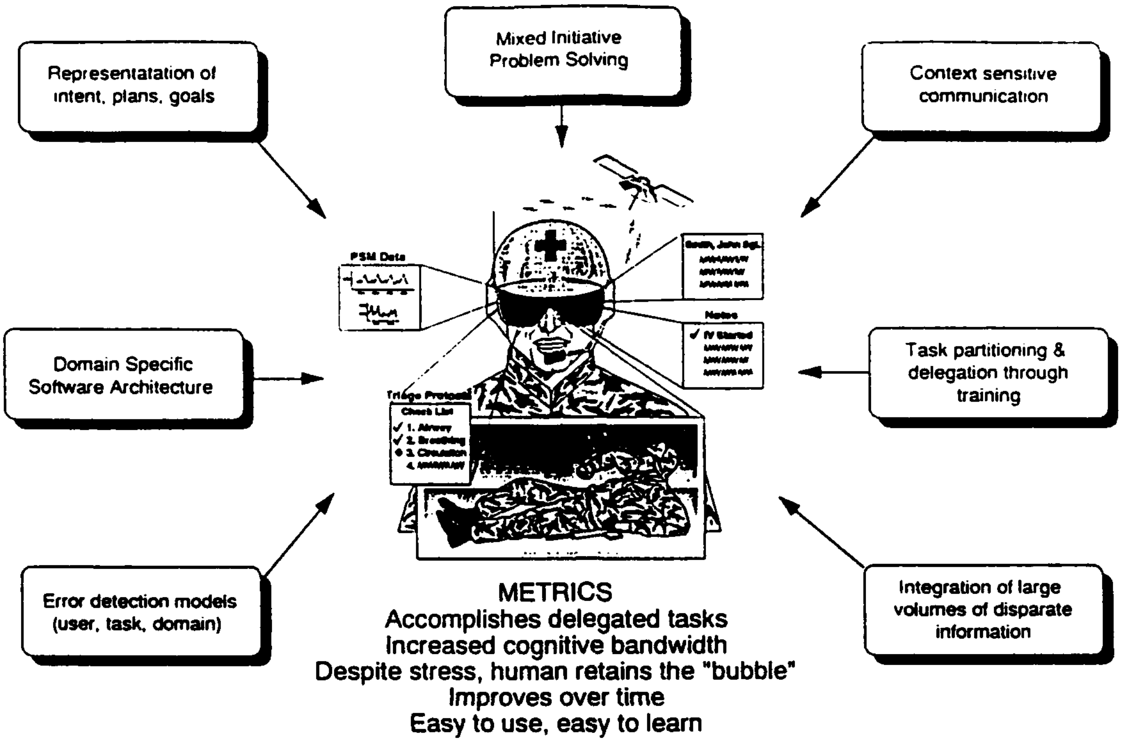
- **Crew Station Automation**
  - Anticipates Info Needs, Assess Potential Plans In Situation Context
- **Trauma Care Associate System**
  - Expert Care (Faster, Patient Record Capture, Less Cost)

ARPA IS 009-93

DISTINGUISHING CHARACTERISTICS:
specific tasks inferred from human's siruration or behavior
human can delegate tasks to computer
value added by human knowledge/sikll amplification and coverege
requires user/domain models, advanced reasoning methods

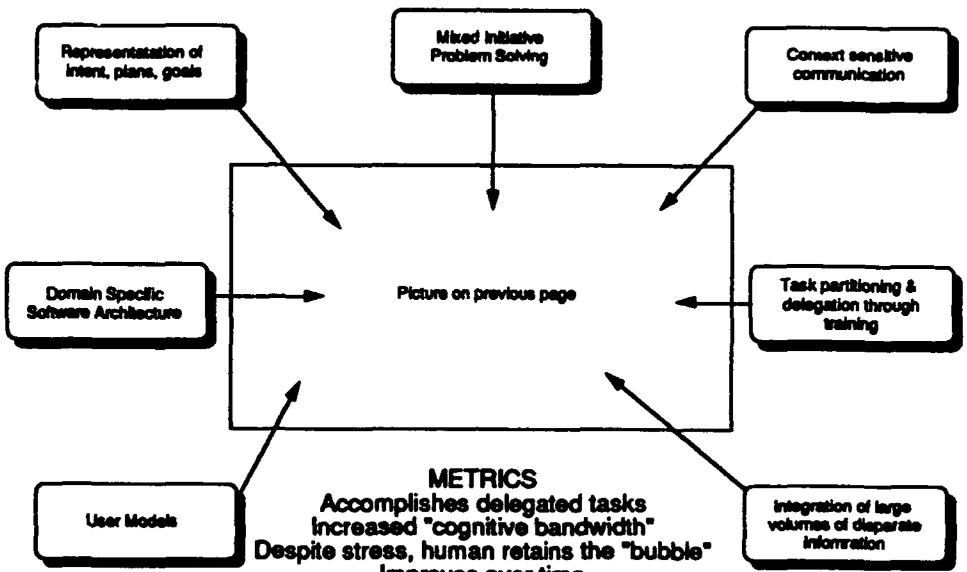
- Associate systems aid humans in the performance of real world tasks such as weapon system operation, trauma care, etc. An associate system monitors the human problem solving and the world the human lives in to prevent errors and to opportunistically initiate problem solving on tasks when the human becomes overloaded. A key idea is that the computer can anticipate information requirements because the computer is able to deduce human goals, monitor an evolving plans, etc. The computer may be delegated to perform certain tasks without human intervention. Learning via training is a critical component in associate system development.

Trauma Care Associate System



- An example of an associate system is depicted in the trauma care situation shown above. The computer facilitates the capture and dissemination of electronic patient records, and displays and helps execute knowledge-based patient protocols - thus amplifying and extending the capabilities of the triage team.

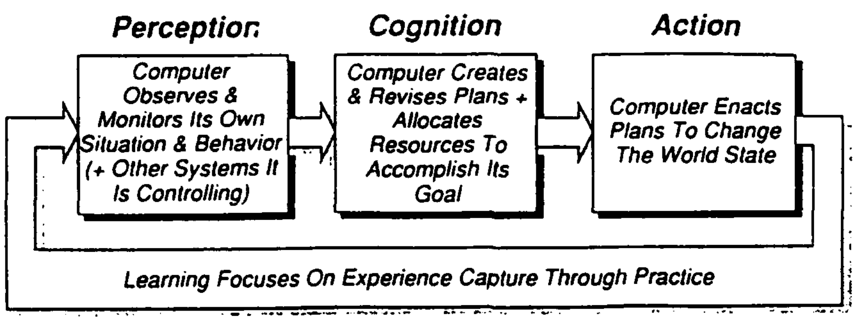
Trauma Care Associate System



METRICS
Accomplishes delegated tasks
Increased "cognitive bandwidth"
Despite stress, human retains the "bubble"
Improves over time
Anticipates needs, "just in time" info

- Many research challenges have to be address to make associate system technology a reality. These areas include representation (of goals, plans, constraints), mixed-initiative planning (shared planning between a human's perceptual strengths and a computer's deductive strengths), models of the user and the user's likely behavior in different situations, learning methods that facilitate knowledge capture during training, and a domain specific software architecture.

Autonomous Systems



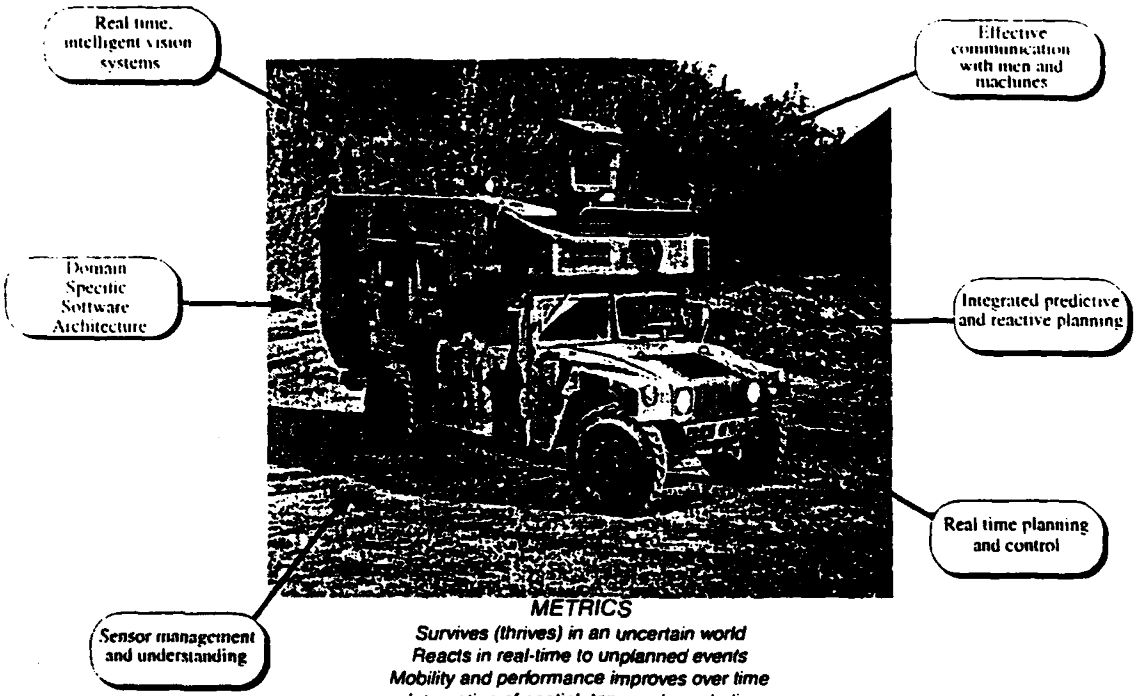
Example:

- **Unmanned Ground Vehicle (UGV DEMO II)**
  - Keep human warfighters out of harms way

DISTINGUISHING CHARACTERISTICS:
specific tasks inferred or assigned from higher level authority
computer responsible for its own actions
mobility
value added is projection of intelligent behavior into unsafe regimes

- The third class of intelligent systems is autonomous systems. An autonomous system is one where the computer develops its own plans and is free (within some set of constraints - for example as imposed by doctrine, Asimoff's laws) to enact those plans. Autonomous systems are mobile - for example, robotics. High performance, intelligent vision systems are critical to the success of autonomous systems. For example, the NAVLAB at Carnegie-Mellon University is able to operate at speeds up to 100 KM/hr.

Unmanned Ground Vehicle (UGV) Demo 2



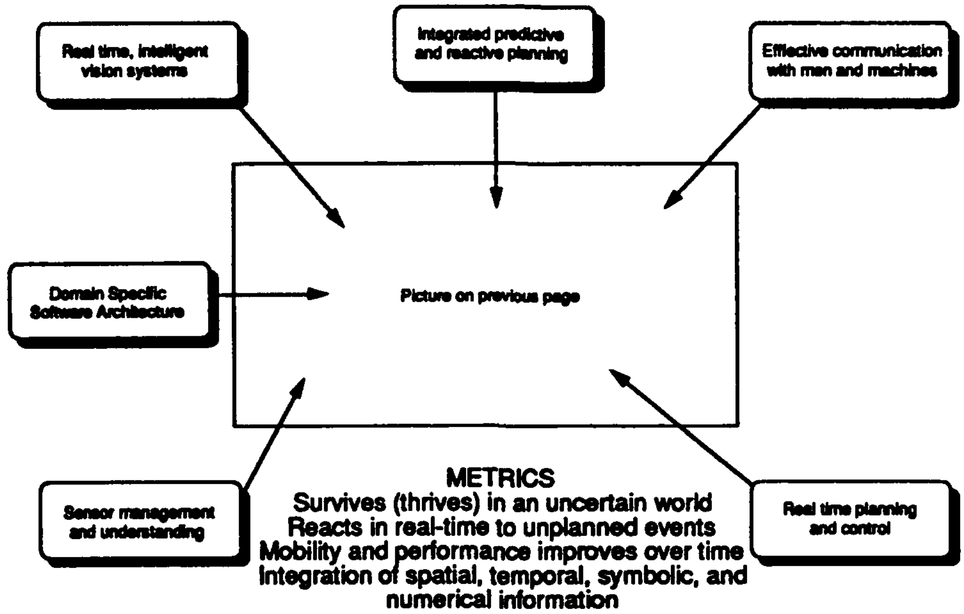
METRICS

Survives (thrives) in an uncertain world
Reacts in real-time to unplanned events
Mobility and performance improves over time
Integration of spatial, temporal, symbolic, and numerical information

ARPA

- A major application of autonomous systems is the Unmanned Ground Vehicle (UGV) program as depicted in the attached figure.

Unmanned Ground Vehicle (UGV) Demo 2



- Major research challenges in autonomous systems include the development of real-time, intelligent vision systems, the ability to integrated planning and control algorithms, new techniques for real-time sensor management and sensor fusion and understanding, effective communication between autonomous systems and human controllers (commanders), and domain specific software architectures to facilitate software reuse and to lower development costs.

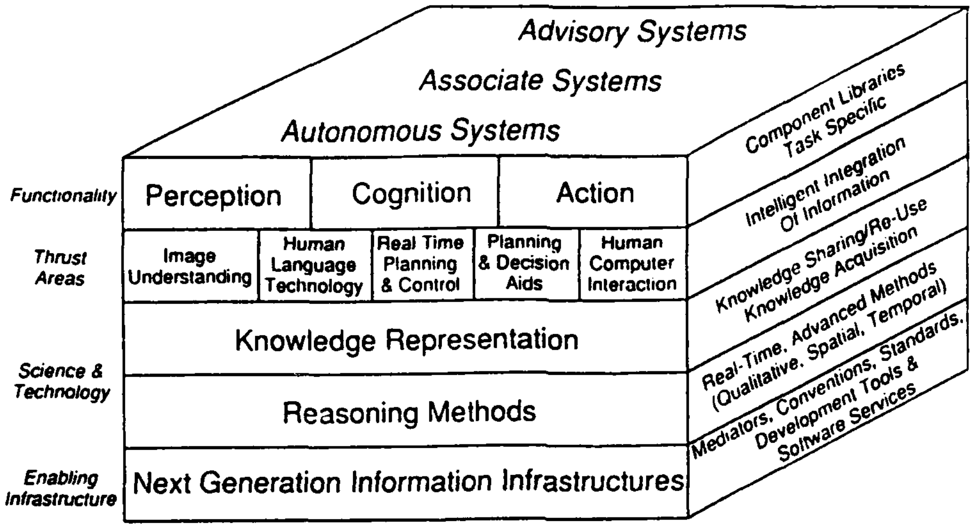
What is the development methodology?

- Conduct a scenario-based domain analysis
- Define the intelligent systems architecture
- Prototype intelligent systems components
- Maximize re-use and re-engineering
- Conduct frequent user-focused testing
- Deliver it in an evolvable form with support tools

Rapid & evolvable intelligent systems engineering:
an unexplored, but critical focus for software research

- Having discussed the different classes of intelligent systems and based on SISTO's experience in a variety of intelligent system projects, we can begin to see a principled development methodology. First, it is critical to develop a realistic scenario of use and to perform a domain analysis on that scenario to determine the intelligent system functionality. Based on the functionality requirements, an architecture is defined. Rapid prototyping techniques are used to develop intelligent system components for this architecture. Maximal attention is given to software re-engineering and se to lower costs. Using the domain analysis and scenario, frequent testing is done with the users. Lastly, it is critical to deliver the system to the users with support tools embedded in the system. For example, an associate system will never be completed - the software must continue to evolve over the life of the system through its interaction with the human counterpart

Intelligent Systems Engineering



ARPA IS 016-93

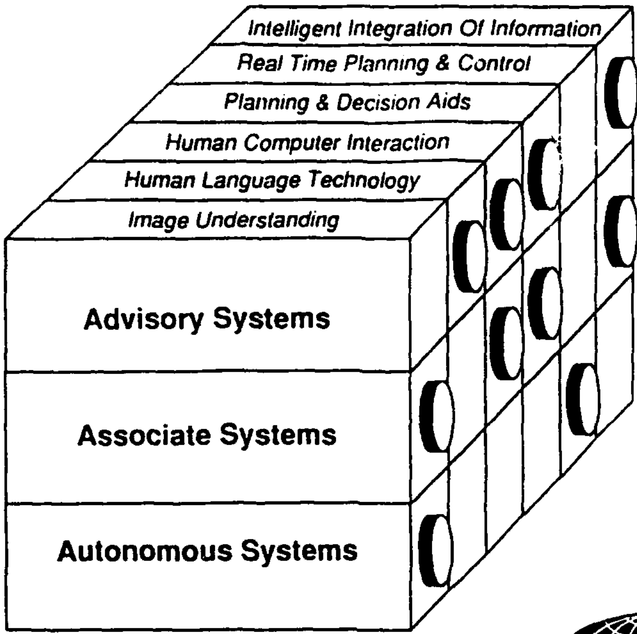
- intelligent systems require a sound engineering discipline to develop and field them. the underlying foundation to the functionality of perception, cognition, and action is dependent on R&D in knowledge representation and reasoning. the goal is to make building intelligent systems easier and to enable a larger group of software system builders access to the techniques. it is a medium range goal to migrate from the present "transcribing manuscripts by candlelight" approach to composition from re-use libraries of knowledge and task specific reasoning modules. the ultimate goals (in fact an absolute necessity) is to have intelligent system components as part of the national information infrastructure.

What is the SISTO game plan?

- pick theme areas that facilitate evolution and integration of ARPA's machine intelligence (& software) R&D programs
- focus integrated teams on grand challenge problems
- encourage use of common frameworks and the sharing of tools, methods, knowledge (towards digital libraries)
- focus new R&D on "technology gaps"
- insist on metrics-based evaluation
- facilitate transition to our customers (military & commercial)

- the SISTO strategy is explained above

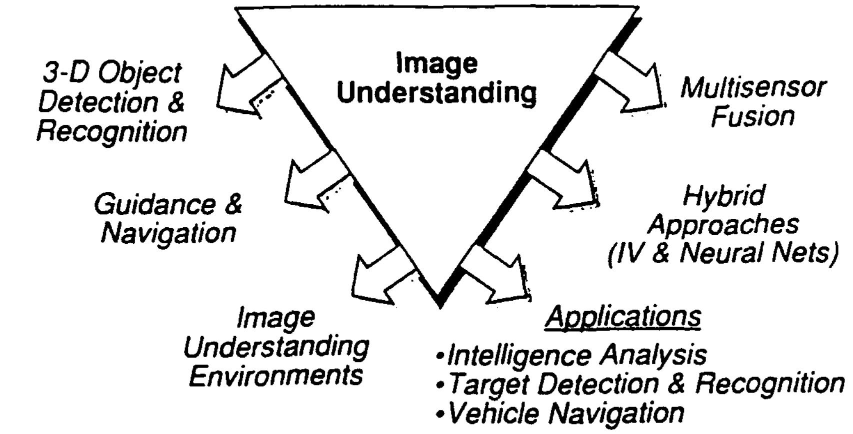
Current Program Emphasis



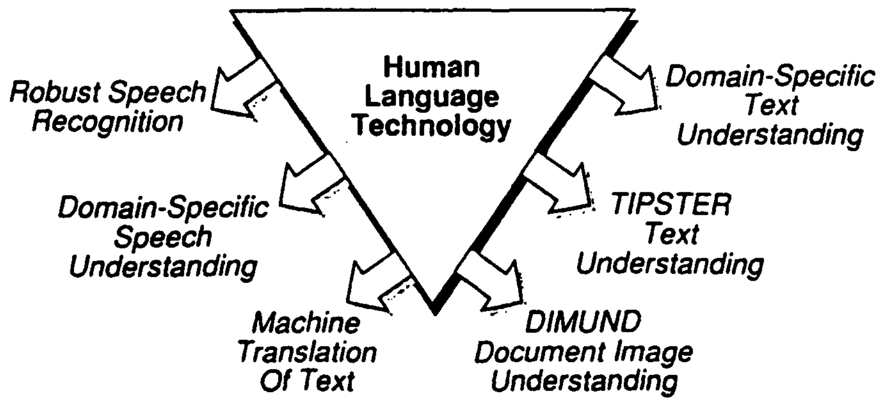
ARPA IS 018-93

- The current R&D program in SISTO includes programs in image understanding, human language technology, human computer interaction, planning & decision aids, real time planning and control, and the intelligent integration of information. Detailed overviews are included as backup. The mapping of these R&D programs to the classes of intelligent systems is shown above.

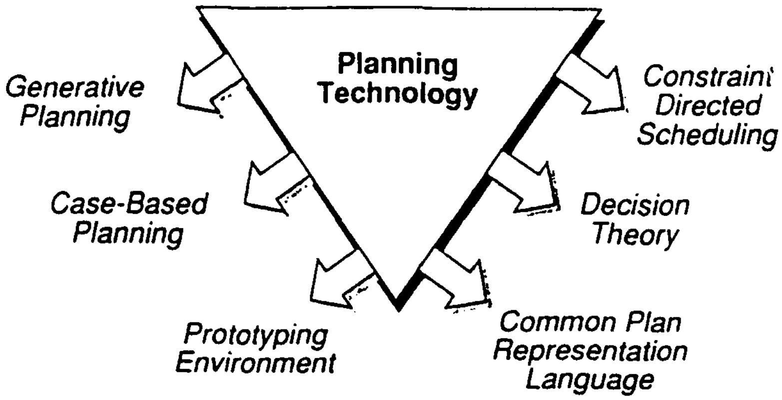
Image Understanding



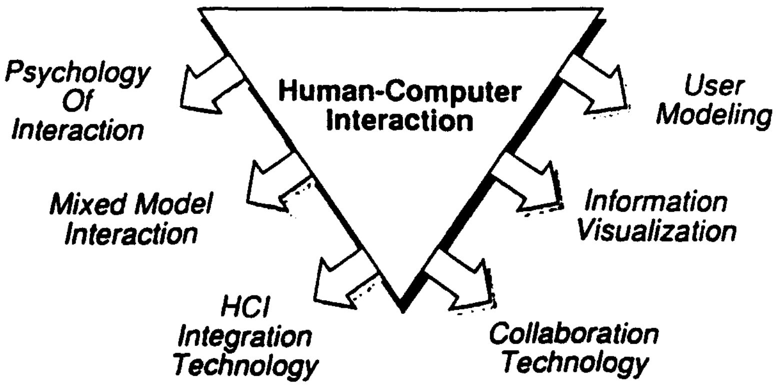
Human Language Technology



Planning Technology



Human-Computer Interaction



Survey

Please fill out one of the survey forms left on your chair at the break

- Are you aware of SISTO results in the following areas?
  - image understanding
  - real-time planning and control
  - planning and decision aids
  - human language technology
  - intelligent integration of information
- Any suggestions on how we can increase your awareness? willingness to apply the technology?
- Classify yourself: a intelligent system technology producer, developer, or potential user
- How important is this technology to your organization?
- What risks do you see in applying intelligent systems technology?
- Are there missing technology thrusts in the ARPA program?
- What tools or tethodologies need to be developed for you to more fully commit to applying this technology?

Request survey results (after July 5, 1993) from:
sisto-info@arpa.mil
fax: 703-522-6367 (5 demerits for not using email)

- We consider you to be out customer. In order to be more responsive to you - we request that you take a few minutes and fill out the following survey.

Additional Information on SISTO Machine Intelligence R&D Programs

- Image Understanding
- Human Language Technology
- Planning and Decision Aids
- Real-Time Planning and Control
- Human-Computer Interaction
- Intelligent Integration of Information

Bottom Line

Intelligent Systems Technology is a key enabler for future DoD & commercial information processing applications

For more information:

Intelligent Systems Strategic Plan
(also to be published in AI Magazine, Winter 1994)

For General Information:

Send email to sisto-info@arpa.mil

For BAA's:

Send email to baa@arpa.mil

ARPA IS 020-93

- In summary, intelligent systems are an important class of technology ideas that will lead to new ways of doing work and qualitative improvements in the DoD and the commercial sector.

III-F Portable Joint Task Force and Command and Control

LtCol Stephen E. Cross

Portable Command and Control for the Joint Task Force

An Advanced Technology Demonstration
June 23,1993

Stephen E. Cross, PhD, Lt Col, USAF
Deputy Director
Software and Intelligent Systems Technology Office
Advanced Research Projects Agency

Outline

- What is the problem?
- What is the technical vision?
- What are the technical goals?
- What is the program elements?
- What has been done to date?
- How will the results transition?
- What is the roadmap? schedule?
- What other programs might benefit?
- Summary

The presentation will address these questions

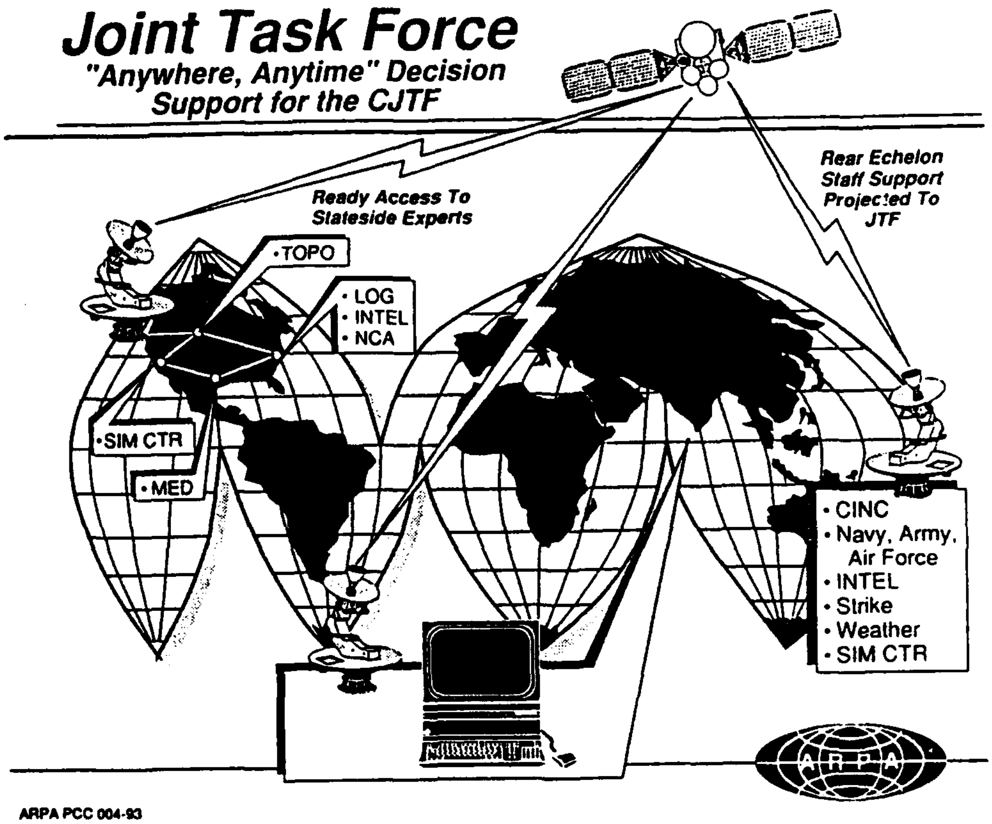
What Is The Problem?

- "Come as you are" wars
- No plan situations
- Multiple crises
- Resource constraints

What is the problem?

- "Come as you are" wars
- No plan situations
- Multiple crises
- Resource constraints

The operational vision for next generation command and control systems must address 4 critical issues. These issues were discussed in the Command and Control Functional ANalysis and Consolidation Review Panel Report (30 Oct 91, unclassified)

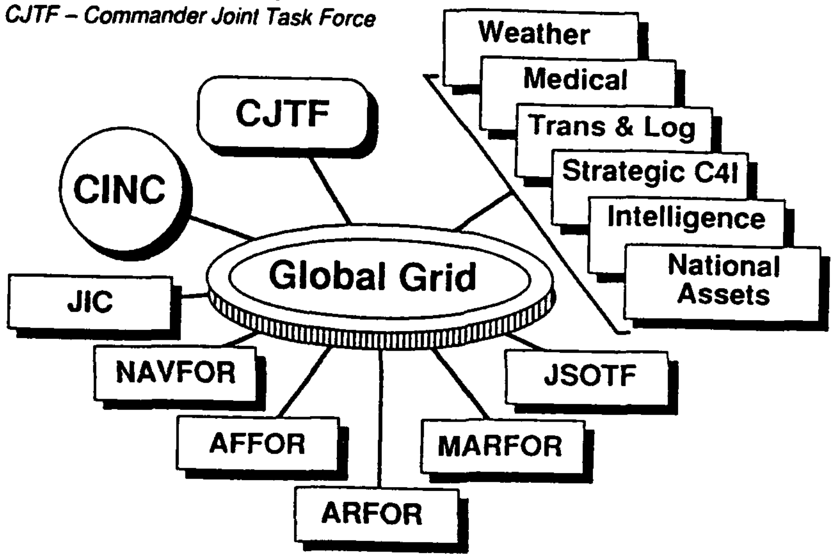


The goal is to provide decision support tools for a geographically distributed staff that are -

- portable --> anywhere, anytime use
- friendly --> natural & easy to learn, adapt, use
- smart --> automates tasks, reduces staff size
- interoperable --> with service C**3 and national assets
- responsive --> fast and flexible crisis planning
- exercisable --> project into advanced simulations

*Two Tier Command Structure: CINC To CJTF**

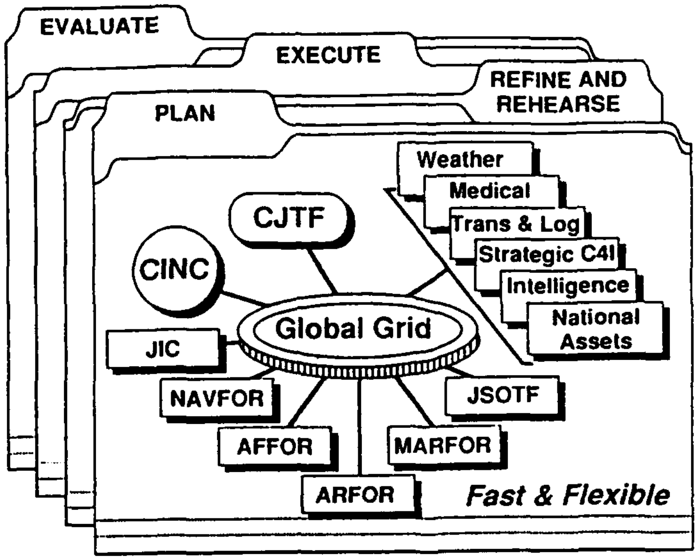
**CINC – Commander-In-Chief*
CJTF – Commander Joint Task Force



ARPA PCC 011-93

The new joint doctrine is two tiered in that a Joint Task Force Commander (CJTF) reports directly to the Unified Command-in-Chief (CINC). The CINC, CJTF, services, and other organizations should be able to communicate and share data/information. It is envision that advanced telecommunications systems will provide a "global grid" to electronically link geographically distributed sites. The development and fielding of this grid is the subject of other DoD programs. The purpose of this project is to develop e the software services and representative applications that could be accessible on the global grid.

"Anywhere, Anytime"
Joint Task Force Decision Support Tools

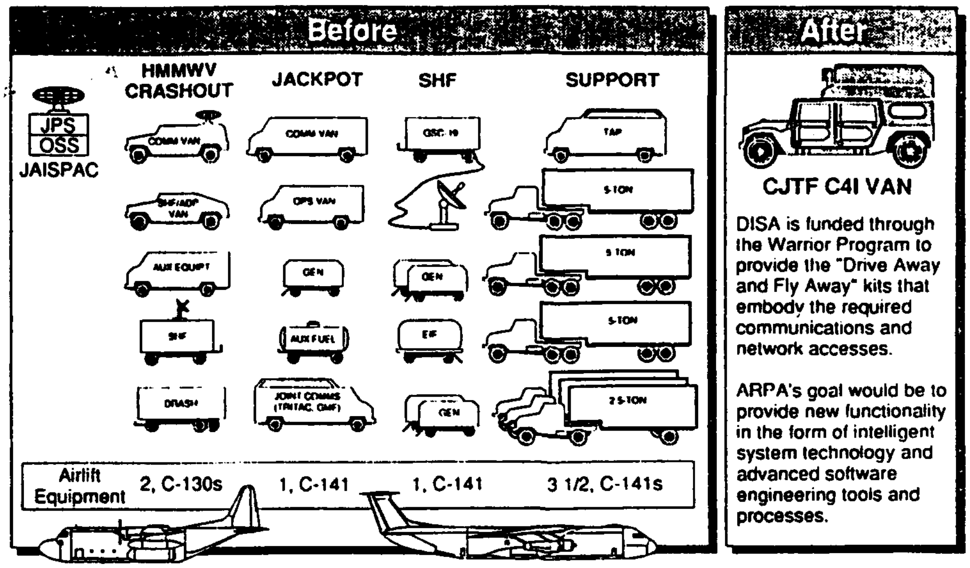


Adapt, Learn, Monitor, and Replan While On The Move

ARPA PCC 010-93

The CJTF should have access to required information "anywhere, anytime" he/she needs it. The concept is "warrior pull" - that is, the CJTF can pull the required information from experts wherever they are. The computer tools used by the JTF staff should enable them to work all phases of a crisis - from initial planning to post-planning lessons learned capture.

*Two Tier Command Structure: CINC To CJTF**



ARPA PCC 012-93

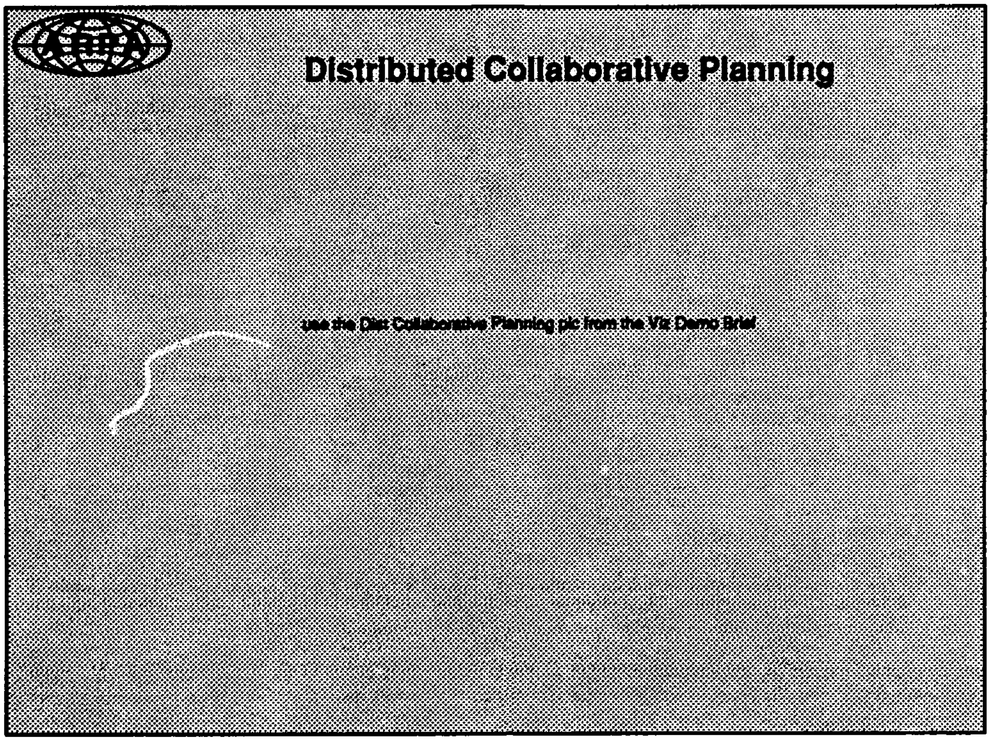
An example early demonstration
Rehosting of ARPA decision aids to a "drive away" kit.
(DART, TIP, COA analysis tools, etc.)

The Problem
Currently USPACOM's J-39 has an
antiquated deployable command and control system.
Upwards of 21 C-141's and C-130's are required to support a deployment.

The Solution
DISA's C4I for the Pacific Warrior Program (working with NRaD) will
field a "drive away" kit with sufficient communications and computer equipment to
support a JTF in a low end crisis (humanitarian relief, NEO, etc) by 3rd Qtr FY94.
ARPA will rehost appropriate decision aids.
Net result - a qualitative leap in PACOM's response capabilities.

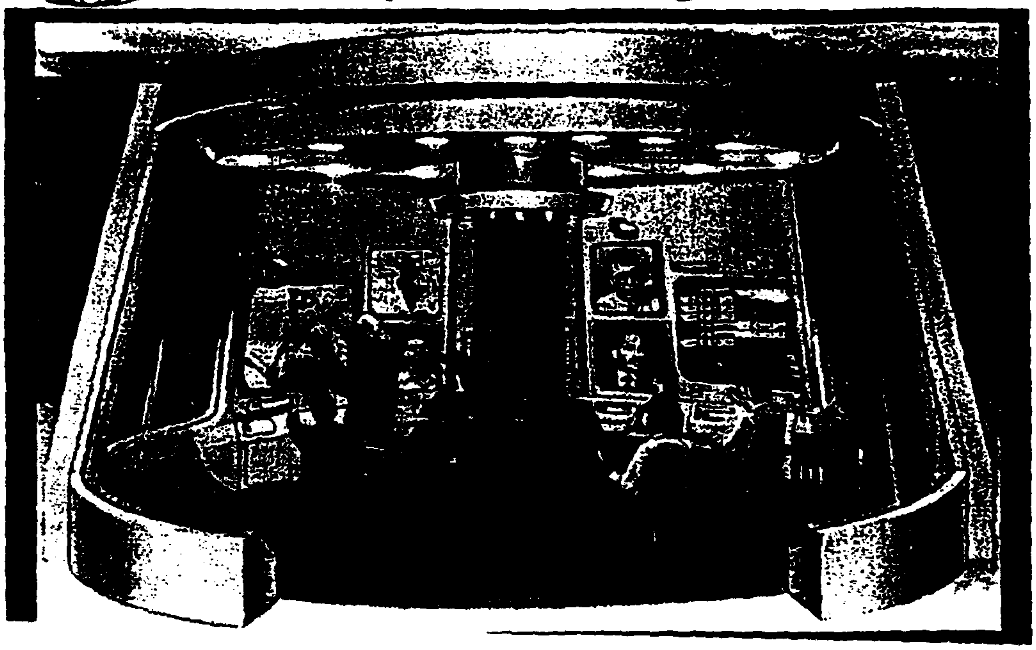
What Is The Technical Vision?

The operational vision suggests many technical visions/dreams that are not immediately achievable.



In the future, crisis action planning will be accomplished by Crisis Action Teams (CATs) that are geographically distributed,

Graphic Planning Cell



A futuristic view of how advanced crisis action teams (CATS) might integrate VTC, high definition displays, high performance computing, advanced decision aids, etc.

Map-Based Interaction

use the Map Based Interaction 2 chart from the "Viz Demo" Brief

One of the new technologies that will be developed is human-computer interaction. And example, will enable users to interact in a "perceptual workspace" as illustrated by this graphic.

What Are The Technical Goals?

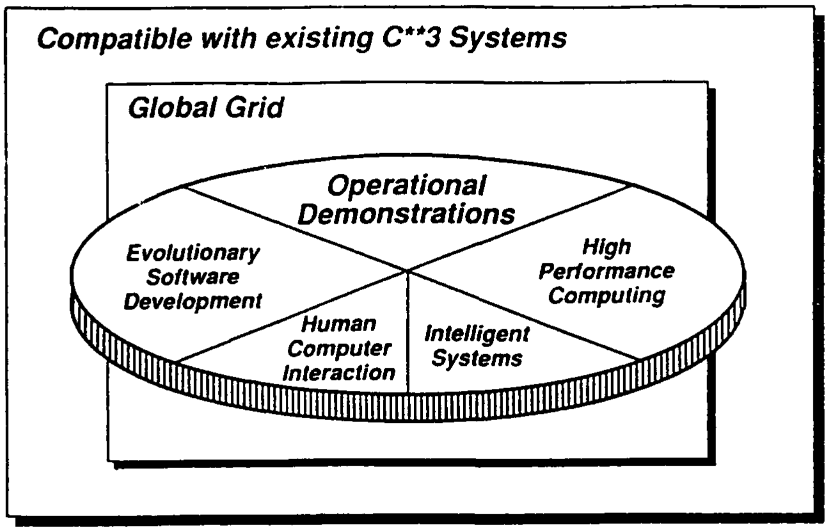
- **Intelligent, user friendly, & interoperable decision aids**
  (100X faster crisis planning with 10X more options)
- **Rapid development and fielding of supportable software**
  (50X faster to field, maximize commercial re-use)
- **Information services for the NII (Global Grid)**
  ("yellow pages", collaboration & visualization tools)

ARPA PCC 006-93

Specific Goals:

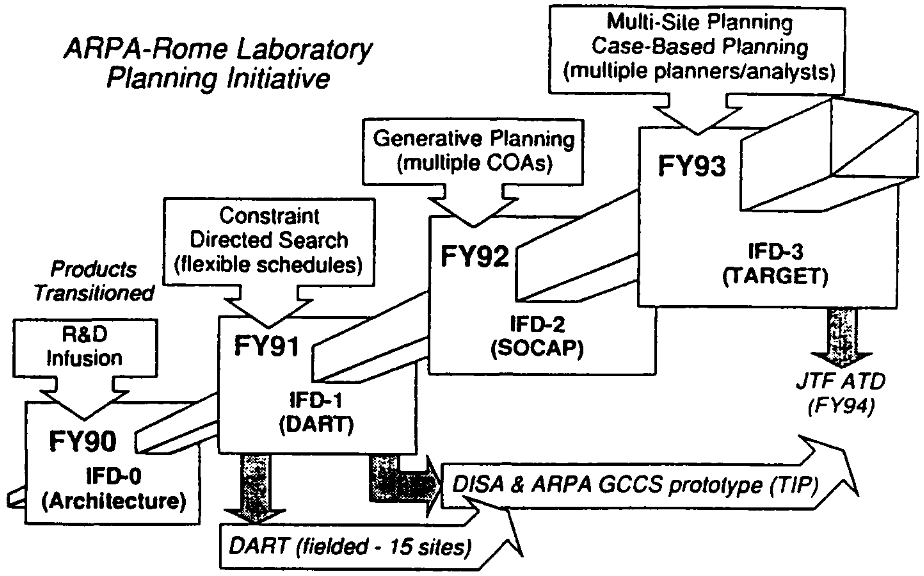
- Enable a fundamental shift in DoD crisis response via direct insertion of intelligent systems and software technology
- Demonstrate & stress test global grid
- Use large scale operational problems to focus the development and integration of intelligent systems and software technology
- Demonstrate modern, innovative software engineering methods
- Measure progress through regular "hands on" use in major operational exercises
- Document the development methodology and champion needed changes to standards and acquisition processes
- Work with an acquisition agency to insure that the new technology transitions into operational use

What Are The Program Elements?



The ARPA Program will concentrate on the top disk. It consists of technology development and demonstrations in the operational community. The resulting software will provide a service and application layer on the global grid. The overall goals is to develop this new technology in a way that it will migrate into existing command and control systems.

What Has Been Done To Date?

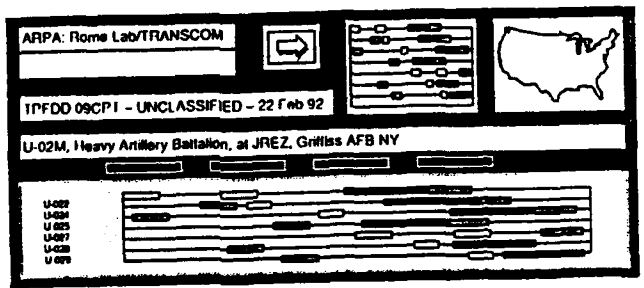


ARPA PCC 008-93

The new program builds on the methods and demonstrated successes of the (D)ARPA-Rome Laboratory Planning Initiative. Since 1990, DRPI has been producing annual Integrated Feasibility Demonstrations (IFDs) that have led to qualitative new functionality. Specific example are discussed in the next two viewgraphs.

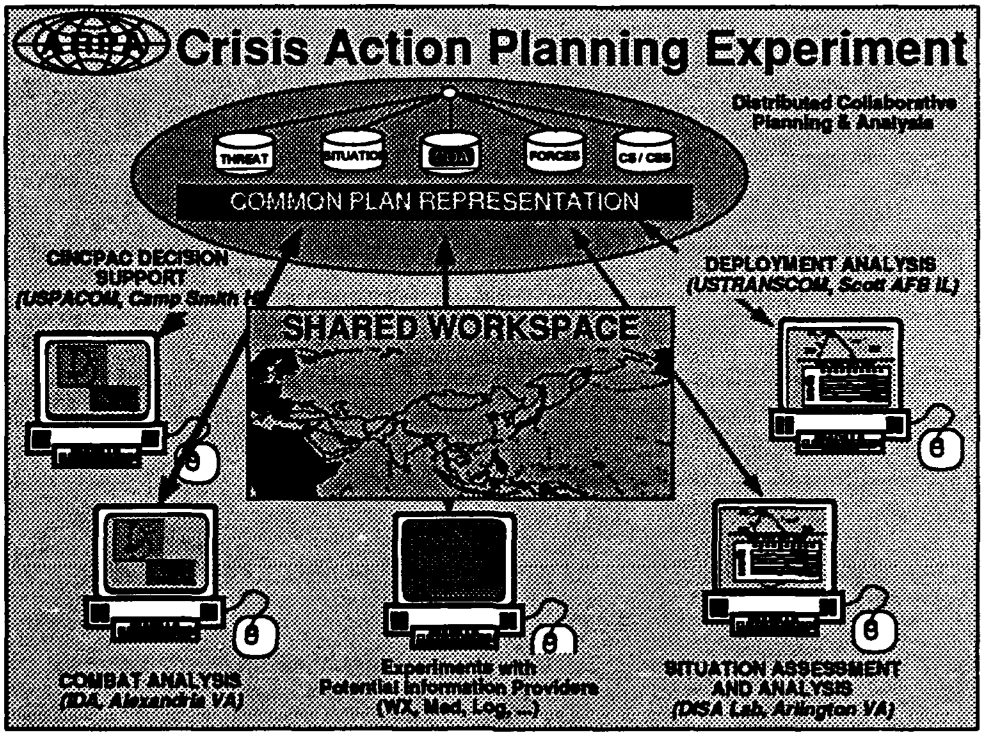
Planning and Decision Aids Program:
The Dynamic Analysis and Replanning Tool

- Use in ODS after intensive 7 week on-site development
- Fielded to every CINC, in daily use
- Early example of commercial re-use
- DART results now impacting Delta Airlines and other commercial companies



ARPA PCC 009-93

DART was developed to address deployment analysis needs during Operation Desert Shield. It was developed and fielded in 7 weeks. It has been delivered to every CINC and has been incorporated as the base for the WWMCCS client-server system (TIP). DART is an example of COTS re-engineering, based on a previously developed commercial airline scheduling system.

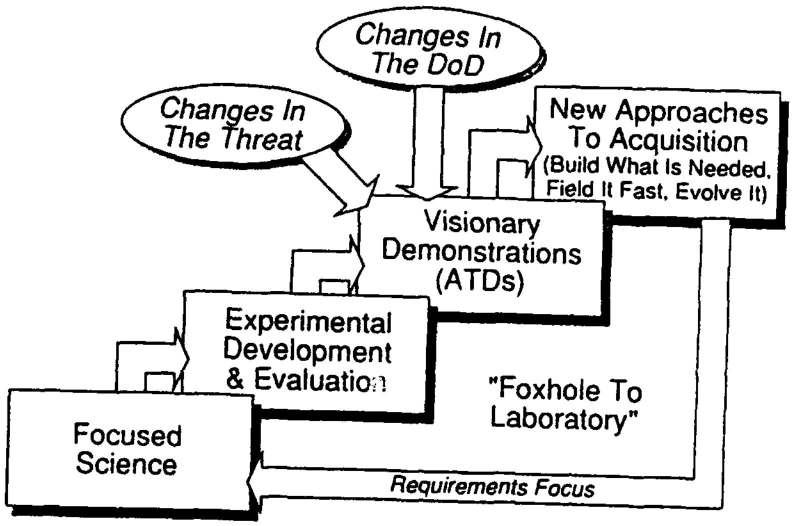


Above picture can be used to explain the FY93 demo - introducing new AI technology for planning aids at USPACOM and have provided a common plan representation to allow interoperbilitity between other previously fielded tools.

Summary of info services on the net
Uses DSINet (T1 capability) - obvious need for higher bandwidth w/more services!!!!!!
Interactive briefing, shared map planning, VTC between all sites
Common Plan Representation facilitates sharing of information and data between tools that were not originally designed to work together.

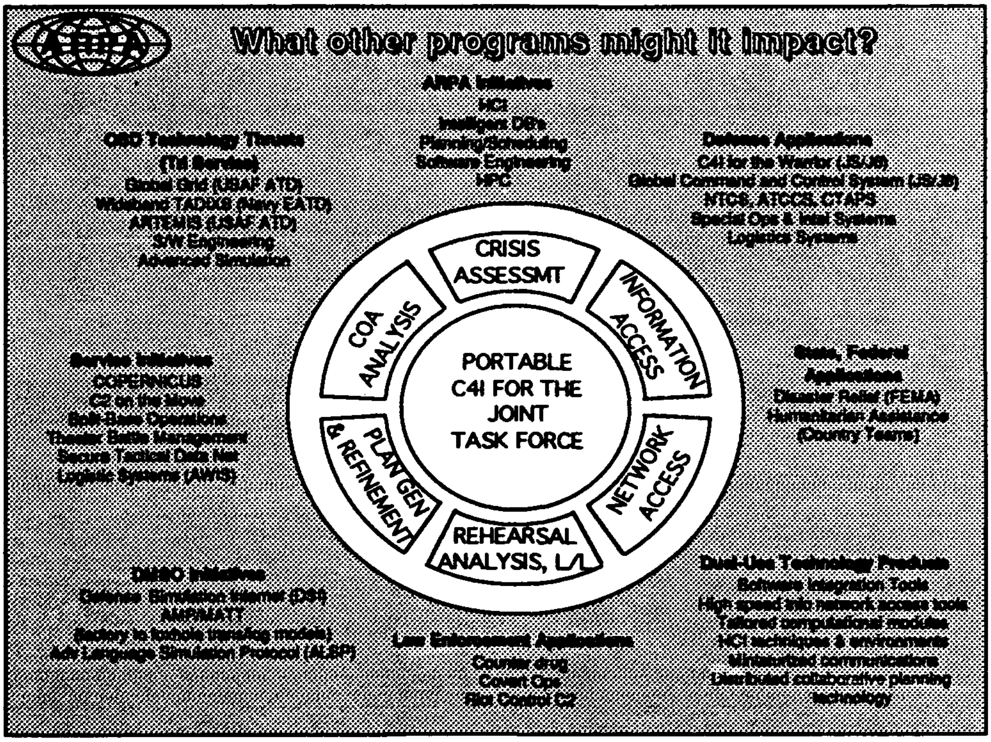
ATD focused on needs of JTF (as opposed to fixed site CINC), adding more "anchor desks" (logistics, medical, etc.), and interoperability with service C**3 systems

How Will The Results Transition?

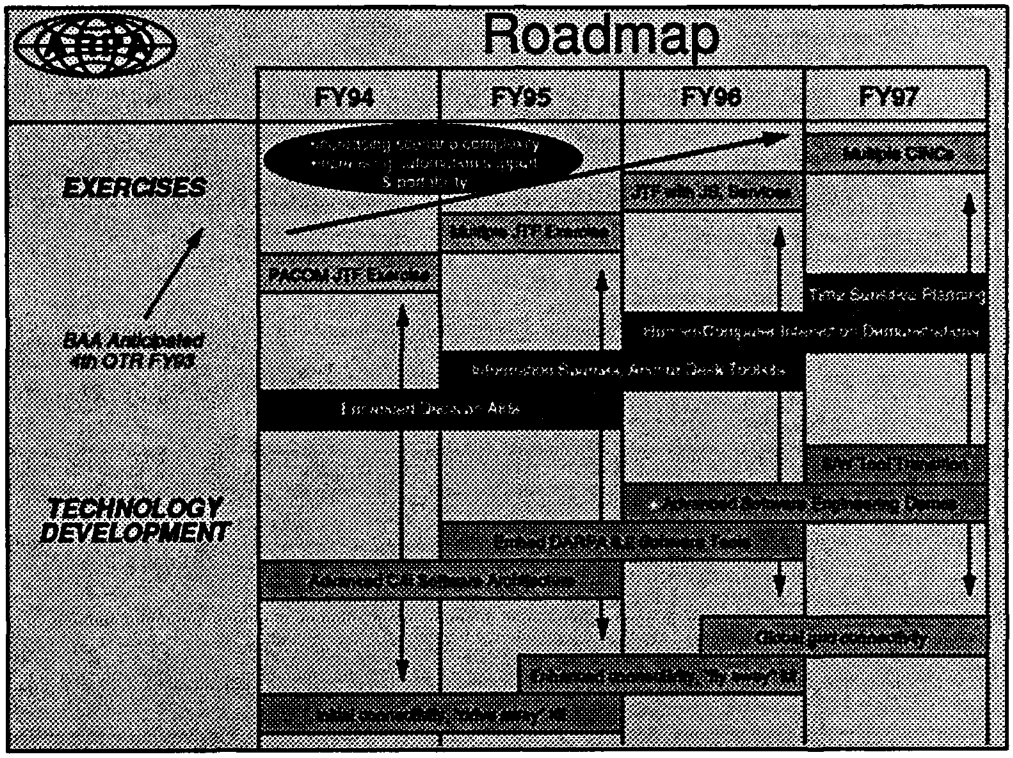


ARPA/PCC 017-93

ARPA will work with acquisition agencies like DISA to insure that next generation C**3 requirements are addressed.



ARPA has briefed to the programs shown above to maximize the potential to transition new technology.



The initial program plan is shown above. A Broad Agency Announcement will be issued late in FY93 with anticipated starts in the 2nd QTR FY94. Annual demonstrations will be linked with planned military exercises. The exact exercises are TBD.

Summary

- Unique Opportunity To Address New C4I Requirements
- Focuses (And Stresses ARPA Information Processing R&D
- Significant Operational Customer(s)
- All Services & DISA Participating
- Technology Reinvestment Opportunities Abound!

This chart summarizes the briefing.
No new information is introduced here.

III-G ENABLING TECHNOLOGY

DR. KAIGHAM J. GABRIEL

"Enabling Technologies"

Ken Gabriel
ARPA/ESTO

a presentation at the

ARPA SYSTEMS & TECHNOLOGIES SYMPOSIUM

June 22-24, 1993

Naval War College
Newport, Rhode Island

Enabling Technologies for Information Systems

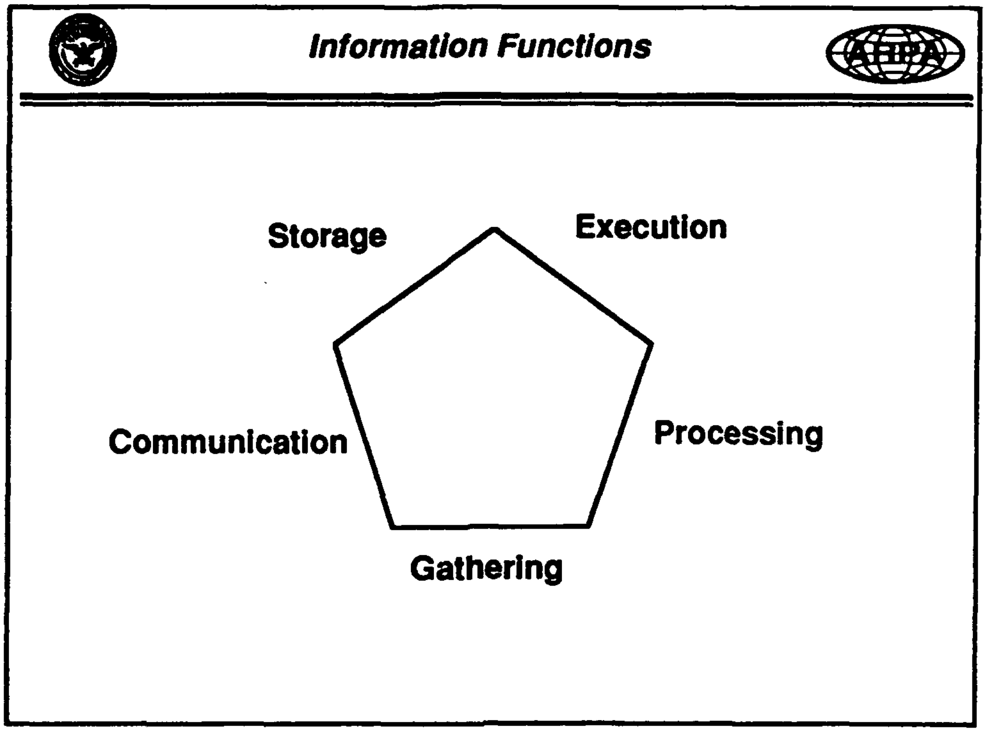
Enabling Technologies for Information Systems

Ken Gabriel

Electronic Systems Technology Office
Advanced Research Projects Agency

(703) 696-2252 kgabriel@arpa.mil

What I'd like to talk about today are some advances in technologies that enable information systems. These technologies are the hardware that make up information appliances and systems, enabling and dictating function and form. They are also the interfaces between humans and the information machines as well as the ultimate executors of the operator will. In part and total, these technologies define the function and delineate the range of information systems.



Before we take a look at the technologies that influence and enable the building of information systems, we need to understand what it is that we do with information. Broadly speaking, there are five things that we typically do with information. They are (in a quasi chronological order): **Information gathering**: whether we type in numbers, keypunch cards,bar code scan, CCD cameras, read sensor data, fax stream, voice input or an optical datastream; gathering information is an integral part of information systems and one that necessarily interacts with the environment and real world (energy, transductions, etc.). **Information processing**: once we have the input from the real world, it's rarely in a form that we can make any sense of. We need to process the data to fit our needs. This is the information function most often associated with "information technology". **Information storage**: although philosophically a subset of information processings, it is an important enough "process" to be separately listed. By storage I refer here to mass data storage over a long time to distinguish from volatile, processing associated memory. Mass data storage relies on a different set of technologies than those associated with information processing (more mechanical & serial). **Information communication**: how do we share information once we gather, process and store it? By what channels, in what form and how fast can we send data back and forth? How do static, fixed information systems communicating differ from mobile and dynamic systems? **Information execution**: This function is the output end of gathering and has a similar diversity of interaction with the environment ranging from visual displays to aiming a tank turret at just the right angle and inclination based on automatic tracking.

Information System Trends

computer mobility

previous information system revolution mainframe ⇨ desktop

next information system revolution

⇩

mobile, embedded, human portable information systems

The next major revolution in information systems is coming about because of mobility. The last revolution occurred when the computer left the floor and the room-sized mainframe and landed on our desks with little more footprint than the monitor used to display the information. This next revolution will come about because computers are poised to leave the desks and go with us as mobile, embedded parts of currently dumb systems that we already interact with (cars, helmets, radios, ...) and some systems that are just beginning to emerge (laptop computers, cellural phones, ...). Some of the technologies that will pace the development of these information systems will be different from ones that drive existing systems including low-power electronics, wireless communication of data and adaptive wireless networks, energy storage and energy conversion, and microsensor technologies.

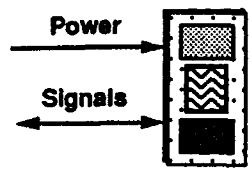
Implications of Mobile Information Systems

- less dependence on
  - visual displays
  - keyboard inputs
- increasing dependence on
  - "natural" interface, some non-visual
    - speech input/output
    - gesturing
    - tactile/kinesthetic feedback
- need for
  - low-power electronics
  - wireless communications & networks
  - special purpose, embedded processors

As information systems become more mobile there will be less dependence on visual displays and less dependence on keyboard inputs. Increasingly, "natural" interfaces such as speech input, gesturing, and scanning devices (cameras, scanner + OCR) will be used to gather and input information. Mobile information systems will also accelerate the need for low-power electronics and increasingly efficient power storage and even power generation devices. Special purpose processors for signal conditioning and implementation of embedded, specialized functions (HMDs, tracking, guidance, surveillance...)will become integral components and manufacturing processes for future information systems. Since vision is the dominant sense particularly for mobile, active individuals, alternative forms of information display including speech, tactile, and auditory displays will be developed and called upon to release the operator's visual system for maneuvering in the real world.

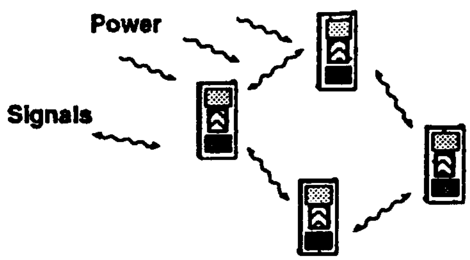
Gathering

Current Use



- **wired power**
- **wired communication**

Distributed Use

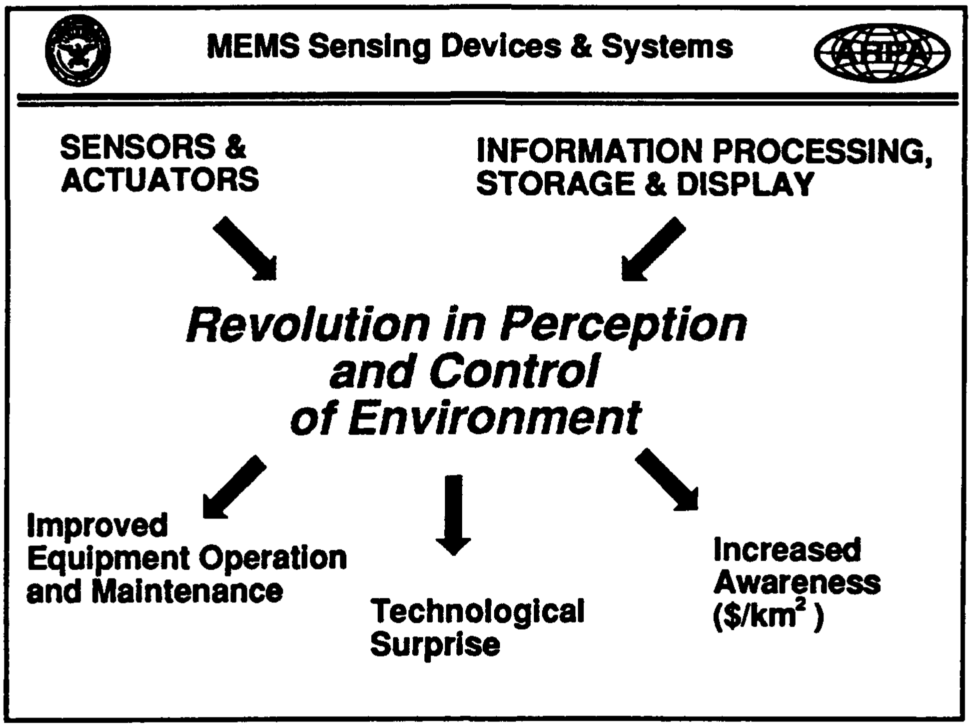


- **wide-area wireless power transmission**
- **low-bandwidth, wide-area wireless communication and interrogation**
- **low-power electronics**

Gathering is the primal function in any information system. Without this step there is nothing to process, store, communicate or display. Enabling technologies that are and will have tremendous impact on the rate at which information will be generated include:

Voice recognition and input: not necessarily increase the rate at which any one user inputs information, but will increase the overall amount of information since almost anyone, infoliterate or not, can dump data into an information system. Hardware technologies that contribute here are low-power electronics (filters and GP processors).

Disributed unattended sensors will increase the rate of spatial and temporal sampling of environments ranging from agricultural and pollution monitoring to HVAC control systems for residential and indusrial buildings. Enabling technologies in these areas include microdynamic devices (solid-state sensors for the sensing of mechanical, thermal, chemical, and electromagnetic energy), low-power electronics, and wireless transponders.

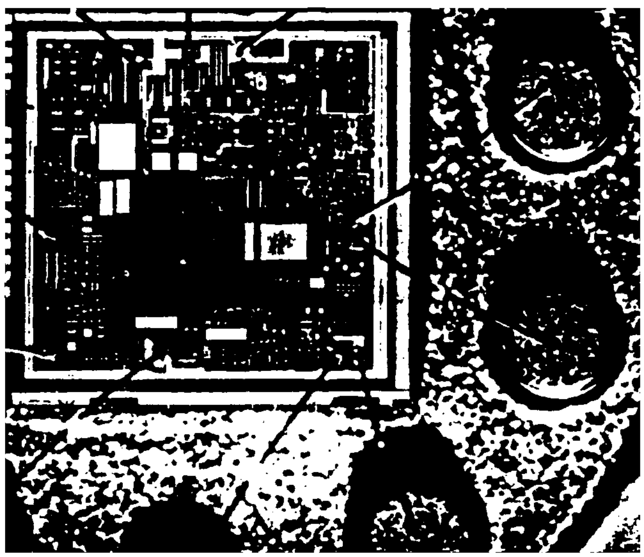


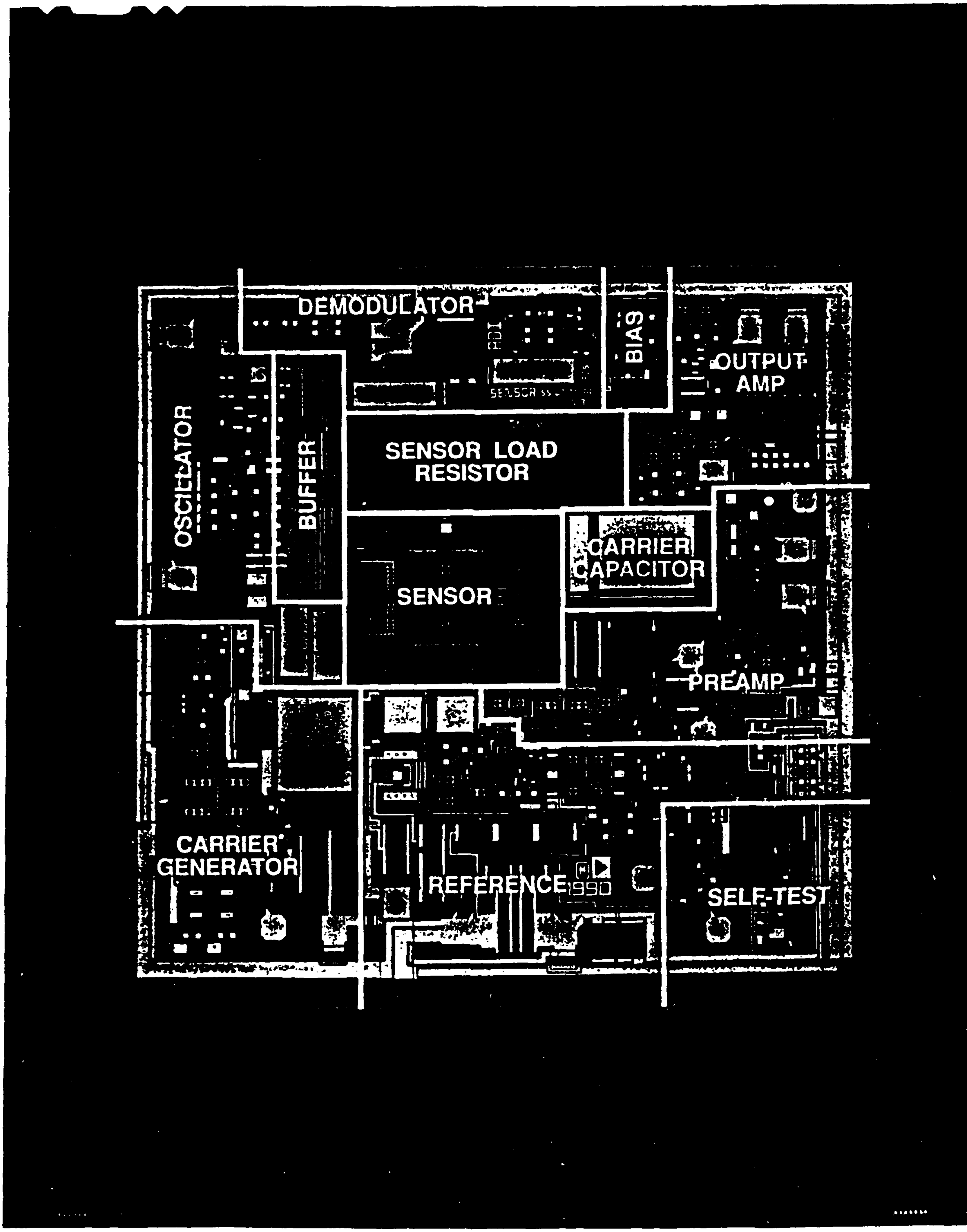
Microelectromechanical systems (MEMS) enable revolutionary advances in the devices and systems used for sensing the environment. MEMS will continue to increase the resolution, type, and rate of information gathered and fed to information systems. The increased gathering capability will impose new demands on processors but also allow unprecedented spatial and temporal monitoring of the environment, manufacturing process, and equipment operation. MEMS is as much a revolution in the way we make electromechanical systems as it is a revolution in the size of electromechanical systems. The three key aspects of MEMS are **miniaturization, multiplicity** and **microelectronics**. MEMS will enable monolithic sensors, actuators and electronics all integrated on the same substrate and fabricated using the same processes. This integration will lead to improved and new functionality including self-calibration, self-testing and the ability to progamm operational characteristic after fabrication. In addition, the multiplicity inherent in the VLSI fabrication allows for alternative design approaches that are impractical to achieve in the macro domain.

Air-Bag Accelerometer

ANALOG DEVICES ADXL-50

Shown here is an example of the first commercially available, monolithic surface micromachined, accelerometer (ADXL-50). It is manufactured by Analog Devices and operates in the 0 - 50G acceleration range with mG accuracies. It is intended for the automotive market as the heart (or maybe the vestibular canals) of air bad deployment systems. Two important points to consider with this device. One, in one common BiCMOS process there are integrated sensors, actuator and electronics. This integration, particularly the actuator is what enabled the commercial feasability of the component. Many of the difficulties associated with using air bags in cars have to do with the expense of self testing and the lack of self-test in previous, solid-state sensors. This device, because the actuator is an integral part of the circuitry, not only has self-test capability but can also be self-calibrating and less prone to damage since it is in a force-feedback loop. Second, it is important to note that the electronics associated with the device takes up more silicon real-estate than the dynamic portions of the device. None of the miniaturization, actuation or multiplicity of the MEMS devices would amount to much with the computational power of the electronics that was cofabricated. The electronics are not only necessary to implement the sophisticated control and test algorithm, but to also enable new distributed and unifying control strategies for thousands to millions of MEMS devices. I will have more to say about this towards the end of the talk in the section on information execution. Here suffice it to say that new levels of sensor resolution and stability can be achieved by electronically merging the operation of hundreds of individual devices than to optimize the performance of any one single device.



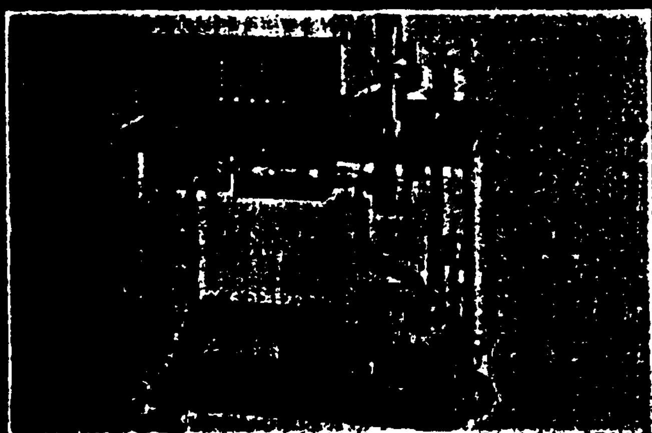

DEMODULATOR
BIAS
OUTPUT AMP
OSCILLATOR
BUFFER
SENSOR LOAD RESISTOR
CARRIER CAPACITOR
SENSOR
PREAMP
CARRIER GENERATOR
REFERENCE
1990
SELF-TEST

WESTINGHOUSE MASS SPECTROMETER

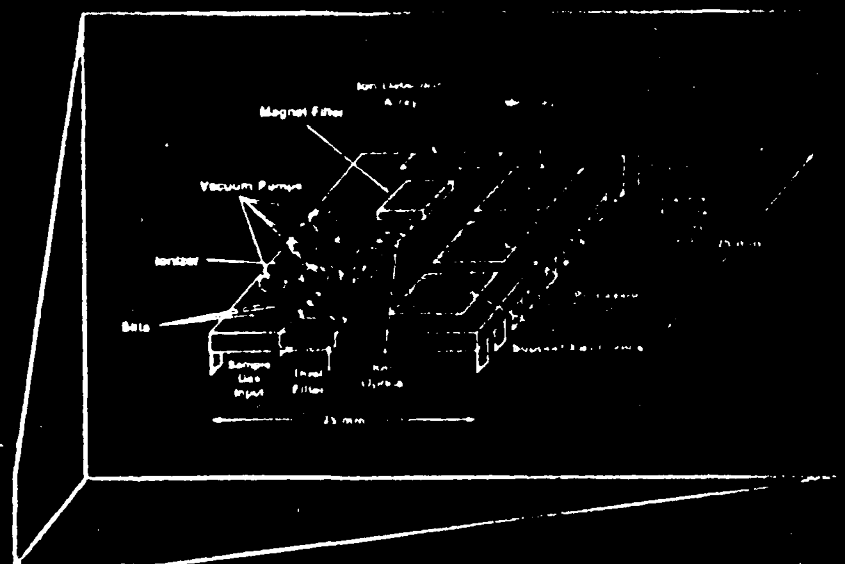
As an example of a completely integrated systems enabling new methods of gathering chemical information, the above represents a project aimed at miniaturizing a mass spectrometer. The key *functional* advantage of this device is its universal gas sensing potential. Existing chemical and gas sensors rely on films specifically tailored for the target chemical species and suffer from (1) volatile performance (short shelf life) and (2) cross talk (not always possible to get a film that only responsds to the target species). The key manufacturing advantage to this device is that through miniaturization and the IC-based fabrication processes used to construct the device, new lows can be achieved in weight, power consumption, size and cost. A critical component in this project is the miniaturized pumping system that will bring the ionizing chamber down to the operating vacuum levels.

Mass Spectrometer Chip for Highly Specific Chemical Detection at Low Cost

Current Technology



$17 K
70 Kg
1200 W
30,000 cm^3



Mass Spec Chip
$20
200 Grams
0.5 W
3 cm^3

Uncooled IR Array

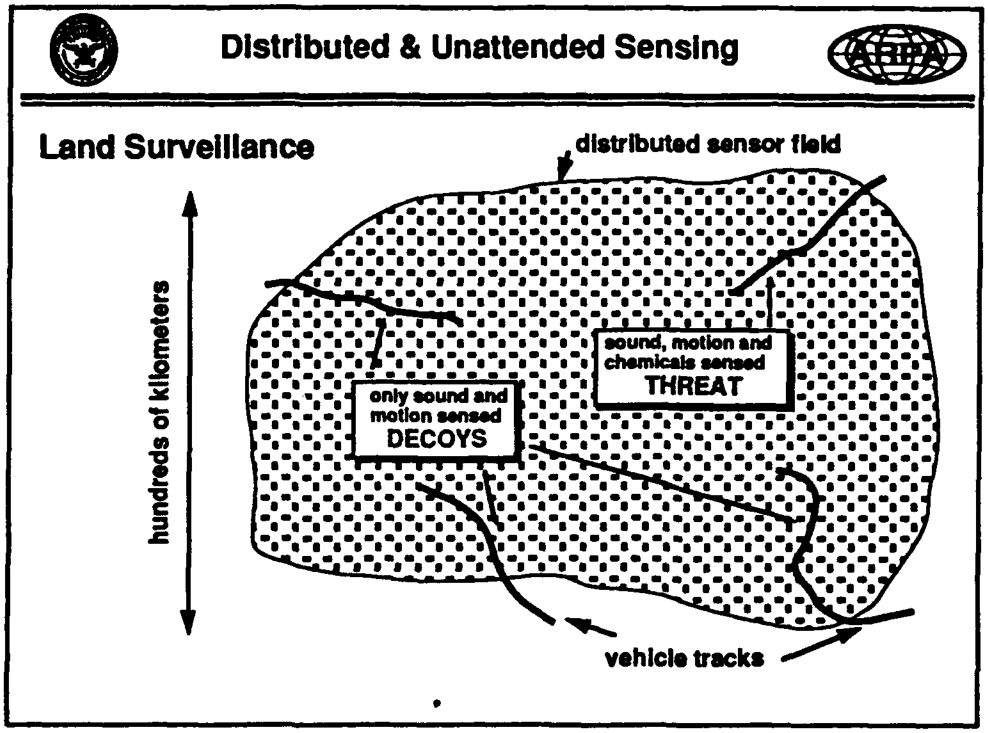
HONEYWELL UNCOOLED IR ARRAY

New types of imagers will change the type and increase the amount of information gathered. Depicted in this picture is an example of one such system that employs suspended bridges of a material whose resistance changes as a function of temperature. As the individual element absorb IR radiation they heat up and their individual resistances change. Since the change in resistance is proportional to the IR energy, arrays of such elements make up an IR imagers. Dual-use applications for such an imager range from portable night-vision devices to process control and collision avoidance sensors for automobiles.

DISTRIBUTED SENSING ON

CONTROL FIN

In this example, the network of sensors is more crucial than any one sensor in the network. By increasing the density of measurements in both the spatial and temporal dimensions, a profile of critical physical parameters can be formed. In addition, by simultaneously sampling different physical parameters at these positions and times, correlations between the various events can be constructed from the information gathered.



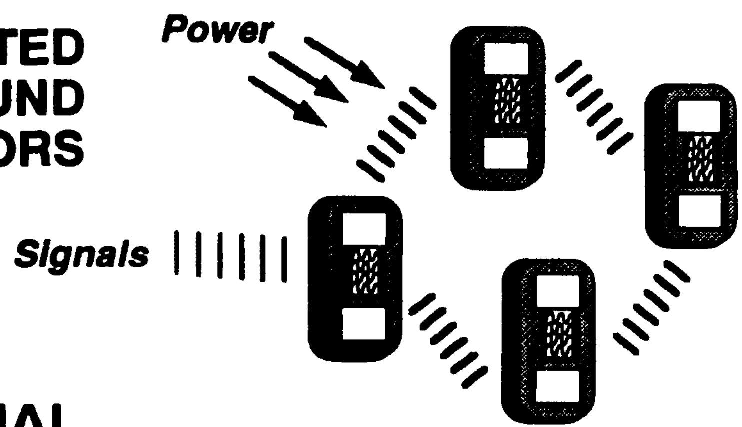
In contrast to the development of commercial wireless systems, the requirements on wireless technology generated by distributed and unattended sensing systems lead to large-scale, low-bandwidth systems. Advances in low-energy signal processing and distributed, multi-sensor systems provide an opportunity for large-area, distributed, low-bandwidth wireless systems. In contrast to the cellular wireless communications, the data rates to or from any one particular end device are very low. However, the combined data rates and coordination of hundreds or thousands of such devices challenge network establishment and maintenance protocols. Many applications will dictate low-capacity or non-existent energy sources in the end radio devices, leading to the use of intermittent, wake-up broad-cast power techniques and novel communication approaches. For example, in environmental monitoring applications, hundreds of disposable end devices with on-board sensing and wireless components would be distributed over square kilometers of area. Activation and interrogation of the sensors/end devices would be controlled remotely and would be required to operate at intermittent, sporadic times over several months.

LOW-BANDWIDTH DISTRIBUTED SYSTEMS

TYPICAL SENSOR FIELD

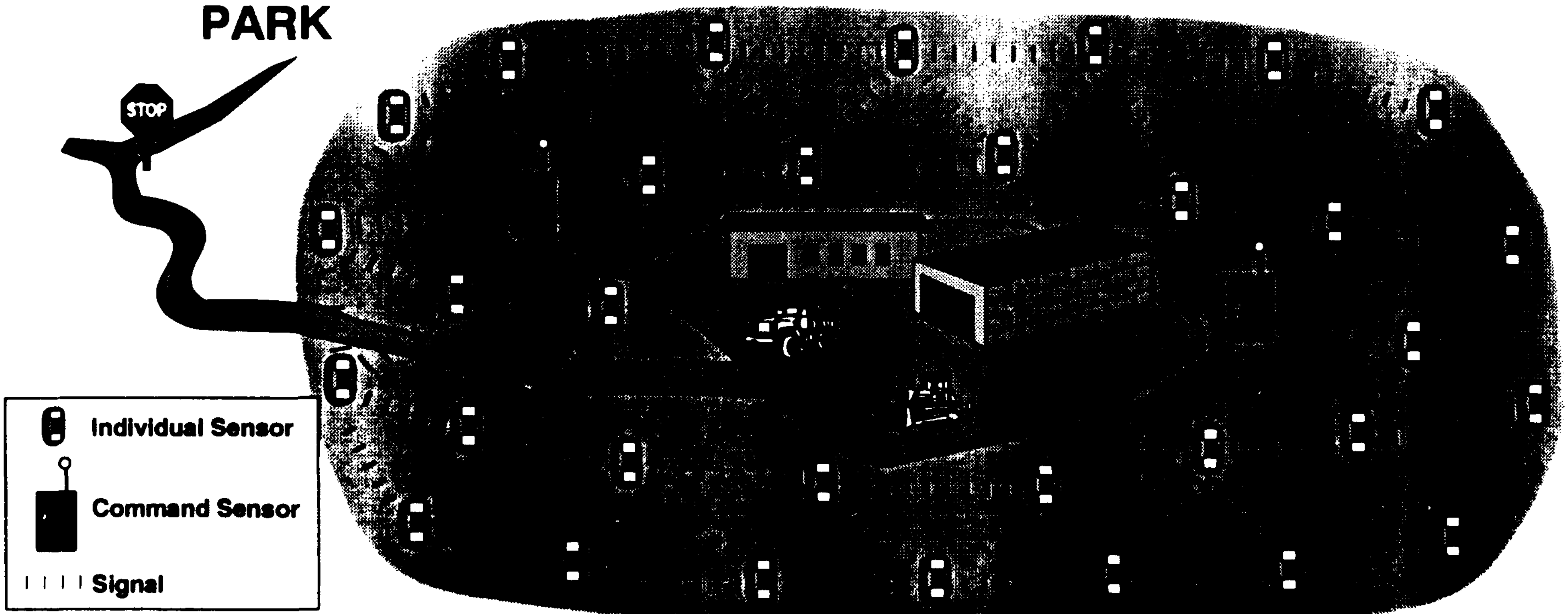
ESTO

DISTRIBUTED GROUND SENSORS



- **Wide-area wireless power transmission**
- **Wide-area wireless communication and interrogation**
- **Low-power electronics**

INDUSTRIAL PARK



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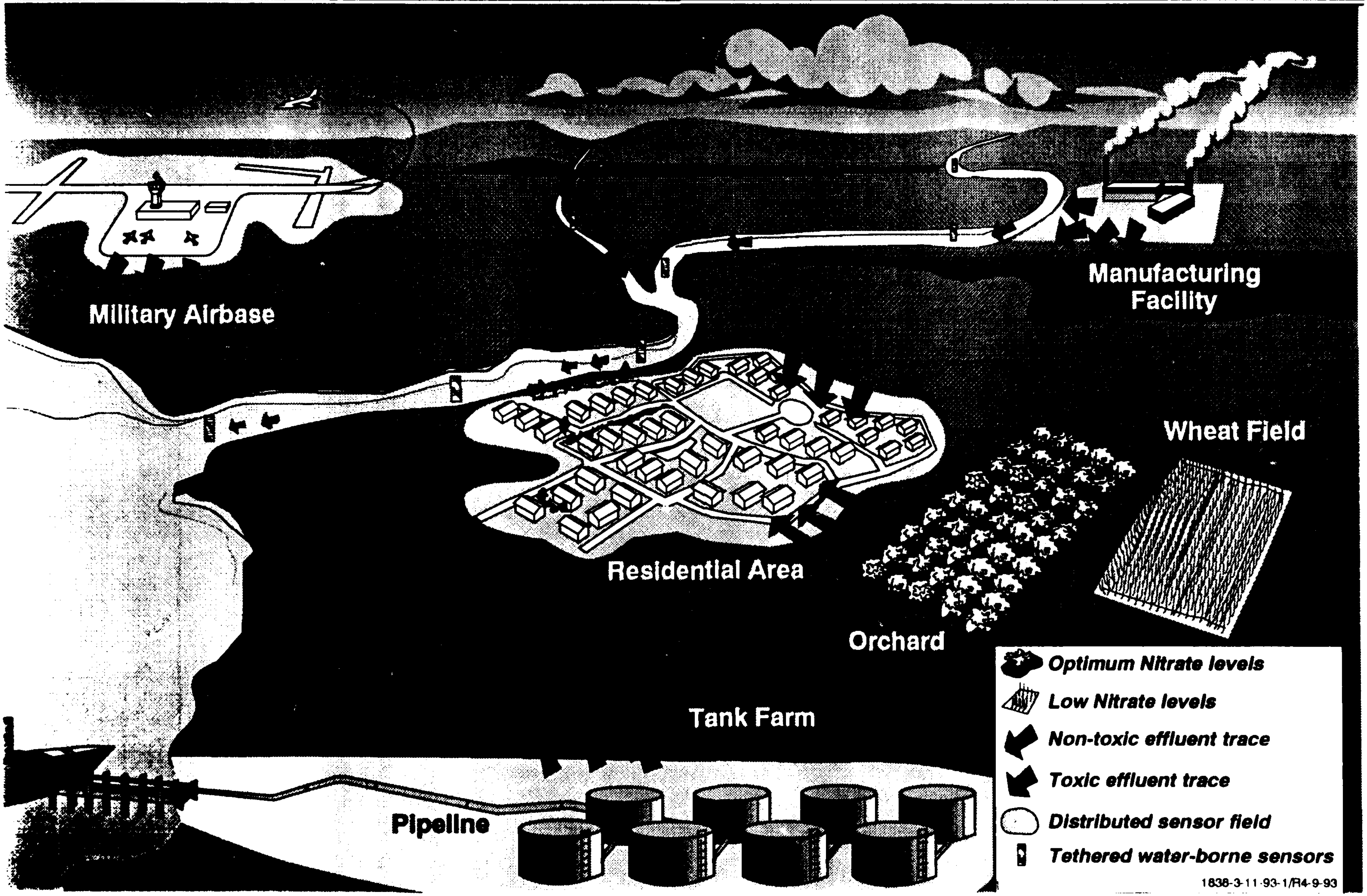
LOW-BANDWIDTH DISTRIBUTED SYSTEMS

ENVIRONMENTAL SURVEILLANCE

ESTO

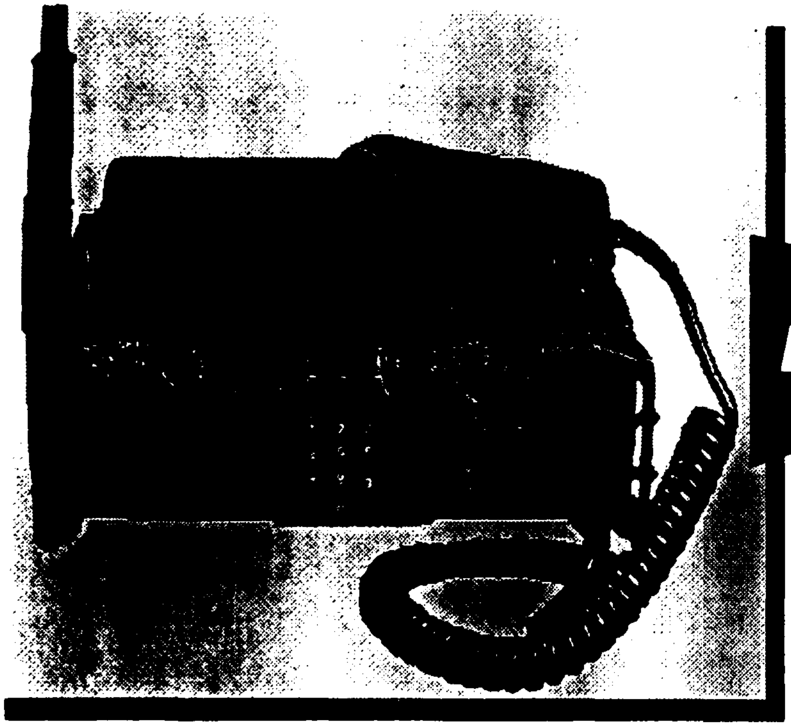


LOW-BANDWIDTH DISTRIBUTED SYSTEMS

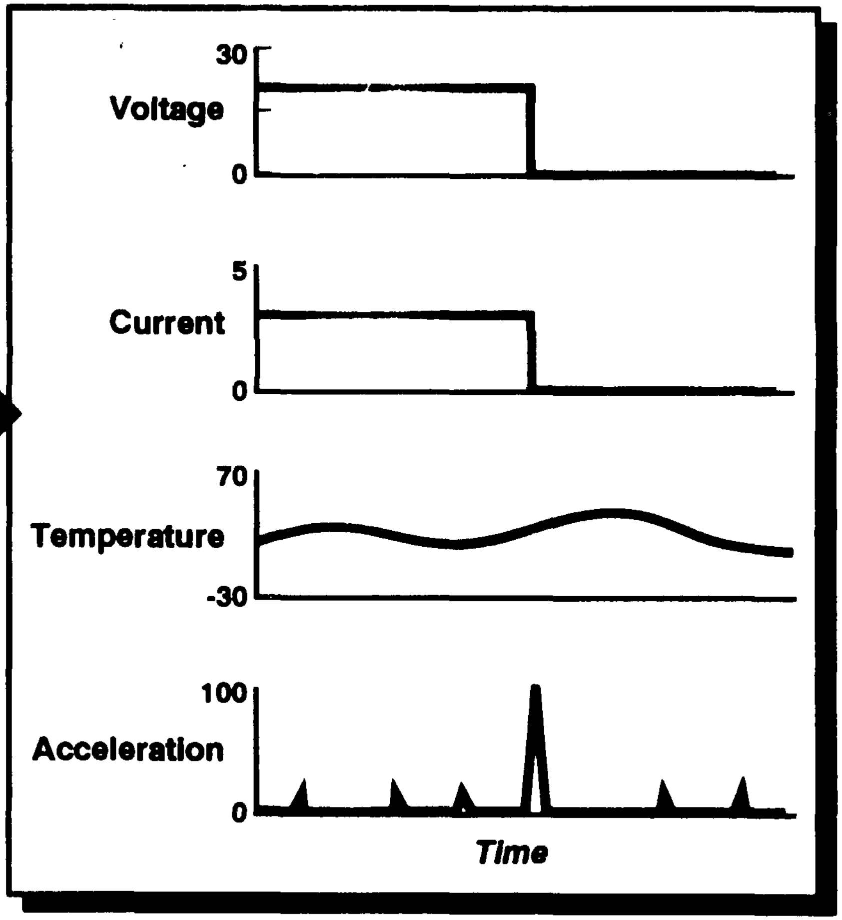
MAINTENANCE

ESTO

Inoperable VHF Transceiver With Embedded Sensors



Recorded Telemetry



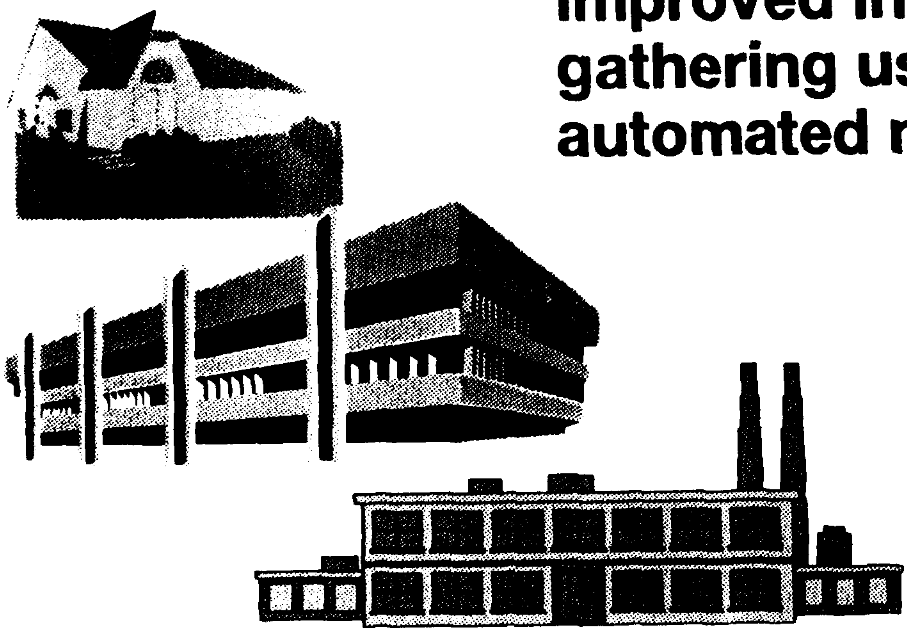
1838-5-11-93-1

Utilities

Los Angeles electricity metering

4.5 million meters need to be read once a month

Average cost $0.56/reading



improved information gathering using wireless, automated meter reading

- more accurate assessments
- reduced cost
- more efficient allocation of resources

Processing

PENTIUM CHIP?

Processing is the traditional,single function most commonly associated with information systems.

Increasing percentages of processing cycle will be tasked by the requirements of information gathering (distillation, categorization ...) and transformations. Data reduction (filtering of raw sensory data) alone will require increased computations rates, but will also be increasingly special purpose and local. It will also be tasked by information execution. Increasing use of virtual reality, and the computations requirements associated with model manipulation and rendering present tremendous processing demands which will be the driver for the next generations of microprocessors.

Special Purpose Signal Processing

RASSP CHIP

As the processing requirements of information systems become increasingly specialized, fewer total devices of any one functionality will be designed and fabricated. This will put increased load on the design tools for special purpose processors and continute to blur the distinctions between signal processing and computation. In addition to more diverse and robust tools, a concomitant development in fabrication processes will also be required. Fewer total devices will lead to increased demand on rapid prototyping and low-volume production techniques. A further goal is to exploit, further develop and integrate emerging technologies to establish state-of-the-art performance and reliability. A key objective is to reduce the total product development time by at least a factor of four while making a similar improvement in product quality. The effective incorporation of manufacturing and life-cycle requirements early in the design process will be an important aspect of the quality effort. Also important will be the ability to insert the latest available technology at system build time and to incrementally upgrade the system throughout its life-cycle.

SELF-CLOCKED STRUCTURES

DOUBLE-AREA HALF CLOCK

As information systems become more mobile, power consumption becomes a key limiter in performance. Two approaches to this problem reflect different ends of the power consumption dimension; one is to reduce the power consumption, the other is to increase power storage or provide for power conversion. Novel architectural and self-clocking schemes are employed to reduce power consumption in the processors and new types of efficient, emmissive visual displays. New battery technologies will increase the power storage capability and increase the operational lifetime of information systems. Energy conversion and storage are also clearly enabling technologies since in many situations we have a lot of energy around but little of it is available in a form we can use (soldiers marching around, heat being dissipated somewhere, bullets [tremendous amounts of stored energy]). One of the more critical factors affecting the duration and extent of military exercise is the cost of batteries. The single component that affects the use of portable information systems (camcorders, cellular phones, laptops, ...) is the battery.

General Purpose Processing

TRENDS IN OPS/CYCLE

SSTO PROJECTS

As information systems move increasingly to portable, mobile systems, increasing amounts of computation and signal processing will be handled by embedded microsystems with special purpose processing. Less and less demand for general purpose processors with varying application programs. Burned in functionality specific and conformal to pieces of hardware will be the norm rather than the exception.

Storage

TRENDS IN DATA STORAGE

Storage is a critical function for a least two of the other functions on the list: processing and communication. Without data storage, gathered information is lost and certain processing steps cannot be performed. Storage and, just as importantly, the retrieval rates of data enable of disable a host of information system functions. For example, hypertext functionality and acceptance will primarily be based on the data storage and retrieval technologies. The days of magnetic storage are not yet over, but even as we reach the limits of magnetic data storage new technologies enable improved magnetic or completely new data storage strategies. For example, fundamental limits on magnetic storage are arguable, but essentially Tbits/sq cm are not unreasonable. Unfortunately, predicted read/write rates using conventional technology do not match up . Even with magnetic techniques, new technologies for moving read/write heads or media will be called for. New technologies will then enable different physical effects for storage including tunneling current sensing of physical holes in the storage media. Using relatively conservative numbers (100Å holes separated by 100 Å) we reach Tbits/ square inch densities with hundreds of micronpositioned read/write heads.

Volatile memory

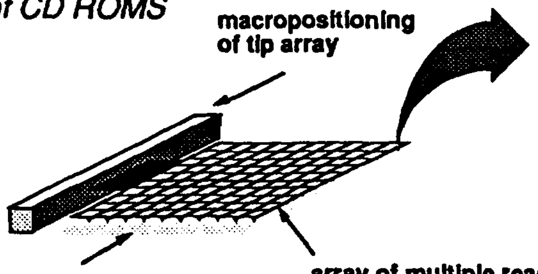
MTO PROJECTS

FLASH CARD TECHNOLOGY

POINTER TO MASS DATA STORAGE

Archival memory

Portable, personal data storage 10^5 times the density of CD ROMS



One soldier can carry <u>all</u> of the maps ever digitized. . . .

WIRED COMMUNICATION

WIRELESS COMMUNICATION

How do I get my information from here to there? The next major revolution in information systems is that they will leave the desk and be a part of things that move with us. Technologies that will have an impact are conformal electronics, wireless communications and low-power electronics. Negroponte of MIT Medial Lab argues that new regulation strategies will be required for use of the electromagnetic spectrum.

Channels

Wired Channels
- **bandwidths**
- **transmission schemes**

Wireless Channels
- **bandwidths**
- **transmission schemes**

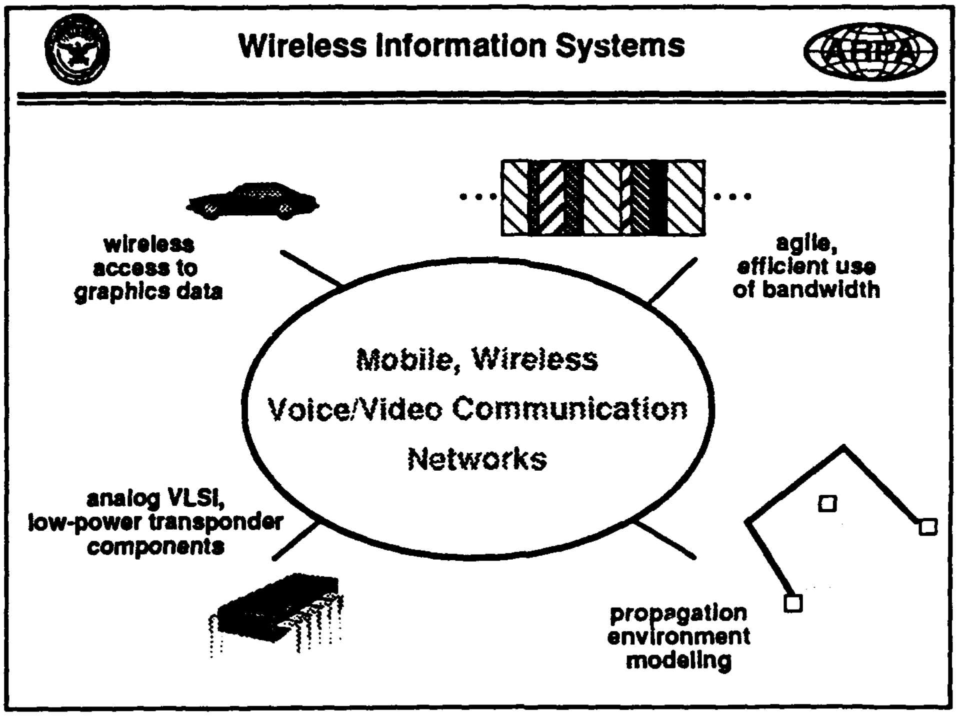
Negroponte of MIT Medial Lab argues that new regulation strategies will be required for use of the electromagnetic spectrum. The EM spectrum will become to precious to use for such static information communication needs like television broadcast. Static communication needs can in theory, be infinitely expanded (bandwidth in the ground). Need more bandwidth, put more cables in the ground.

Wired Information Systems

Internet

Implications for distributed
- information data bases
- design collaboration
- virtual organizations
- distributed manufacturing

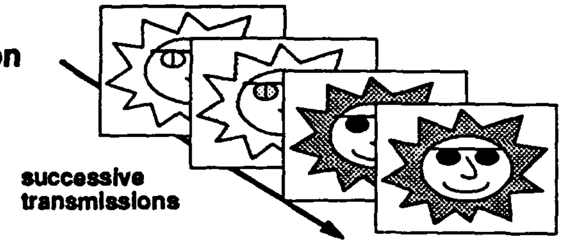
FIBEROPTIC CABLING
CONNECTORS



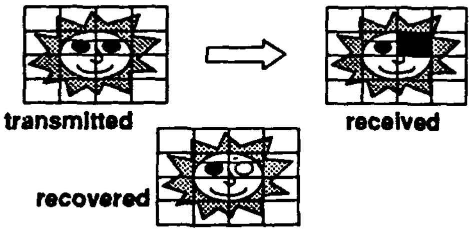
The EM spectrum will become to precious to use for such static information communication needs like television broadcast. Static communication needs can in theory, be infinitely expanded (bandwidth in the ground). Need more bandwidth, put more cables in the ground. The EM spectrum, which is non-renewable will be used solely for mobile, dynamic communication needs. Free, long-lasting electrical energy for high-performance information systems will mean less and less time spent on desiging control boxes for things. Use example of Red Top Cab company and their use of wireless computers to improve taxicab services (rapid response, avoid passenger confusion, fair distribution of assignments...). Wireless networks will require dynamic naming conventions, new transmission schemes, integration of positioning and tracking technologies.

Bandwidth Issues

Coding & Transmission Schemes for Variable Bandwidth & Integrity Channels



Coding & Reconstruction Schemes for Error Recovery



Execution

THE OUTPUT OF INFORMATION SYSTEMS

visual displays

valves turning on or off

Displays are the most obvious and importnat execution technology available to information systems. How long this lasts is up for grabs, but displays will likely to be the principal means for interacting with humans. The form and type of displays will change (head mounted displays versus static desktop display, see-through versus occluding dispays), but they will be displays never the less. Microdynamic devices and systems offer increased control over the environment by enabling information execution of a completely different type. Rather than display a flashing "shut off valve 8" on a video screen, the information system will have available to it the means of executing the shutoff directly. Not only will MEMS increase the number and the affordability of such information executors, they will change the way such executors are designed, fabricated, and operated. Coupling information systems with the distributed information gatherers and the information executors will enable finer grain control over manufacturing processes, environmental monitoring and equipment operation & maintenance. New levels of reliability, functionality and efficiency will be achieved in many systems including vehicles (automotive, aerospace and maritime) and HVAC (for residential, commercial and industrial buildings).

Displays

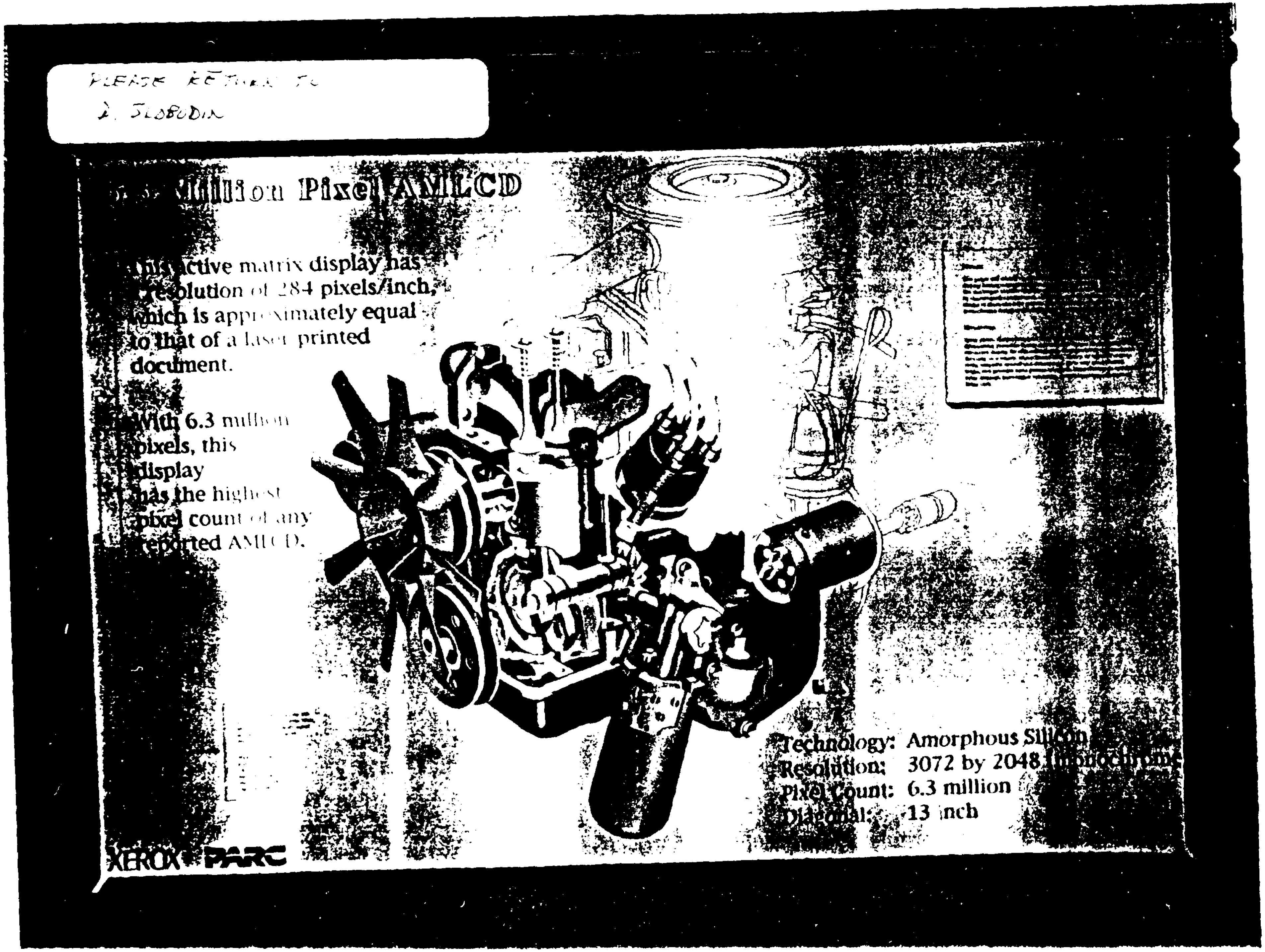
NON VISUAL DISPLAY

MOBILE INFORMATION CONTEXT

- speech
- tactile

Visual displays are the windows onto information systems. They will continue to pace the development of static, desktop information systems. High definition systems are the integrated hardware, software, and networks that enhance the data used to make decisions in time-critical military environments. Display efforts include improved cathode ray tubes; flat panel and head-mounted displays using active matrix liquid crystals, electroluminescence, plasma, and cold cathode technologies; projection displays using digital micro-mirrors, liquid crystals, and laser projection; as well as efforts in manufacturing and enabling technologies. Display processor efforts include: development of high speed video processor modules, workstations, high bandwidth busses, image transmission over packet networks, and a high bandwidth, digital compressed video and data system for education and training. New graphics tools, graphics standards, and user interfaces are being developed. Research on virtual/augmented environments and scientific visualization is being conducted.

Xerox 6.3 Megapixel Display


PLEASE RETURN TO
D. SLOBODIN
Pixel AMLCD
This active matrix display has a resolution of 284 pixels/inch, which is approximately equal to that of a laser printed document.
With 6.3 million pixels, this display has the highest pixel count of any reported AMLCD.
Technology: Amorphous Silicon
Resolution: 3072 by 2048
Pixel Count: 6.3 million
Diagonal: 13 inch
XEROX PARC

Emissive Display Example

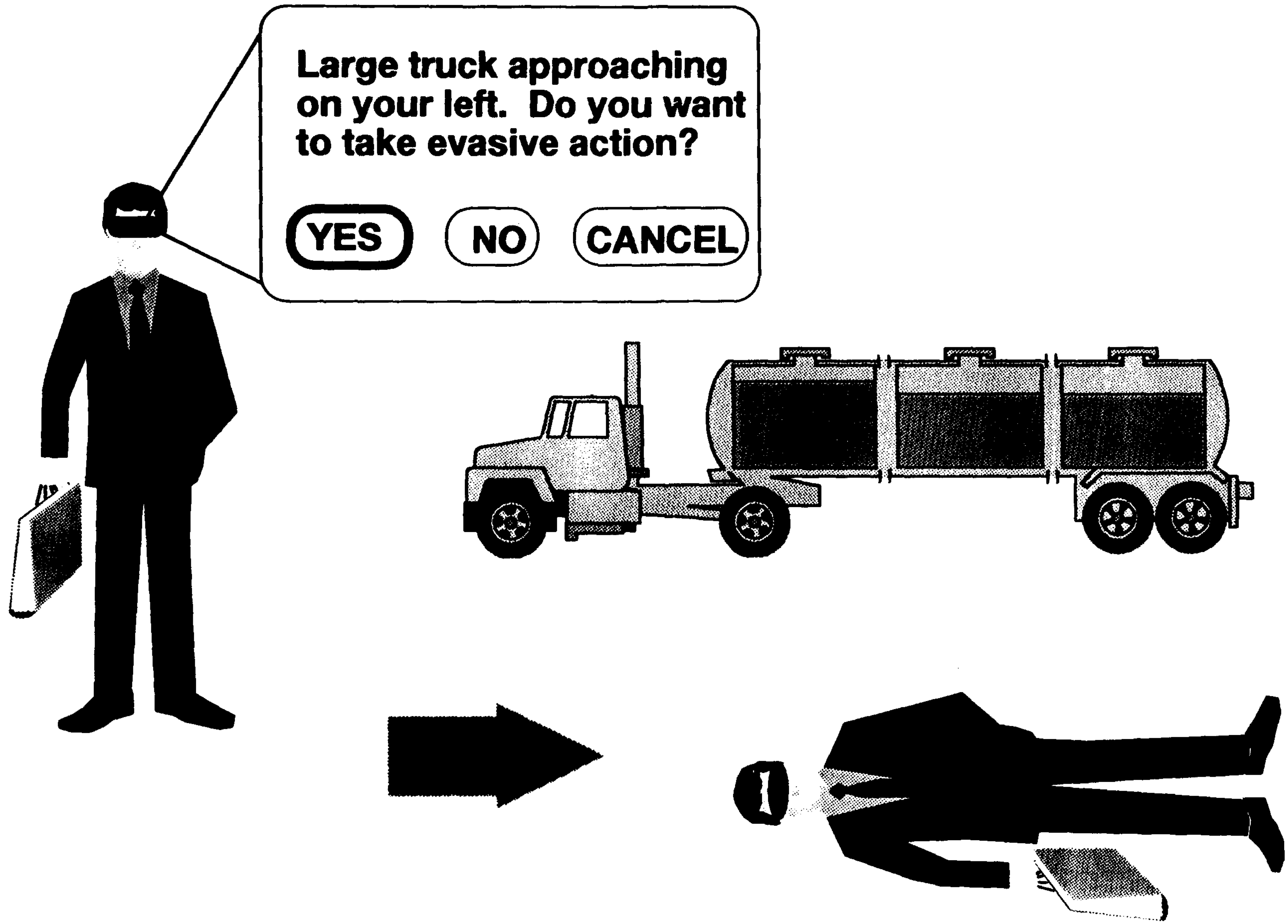
Stanford Deformable Grating Display

Non-Visual Displays

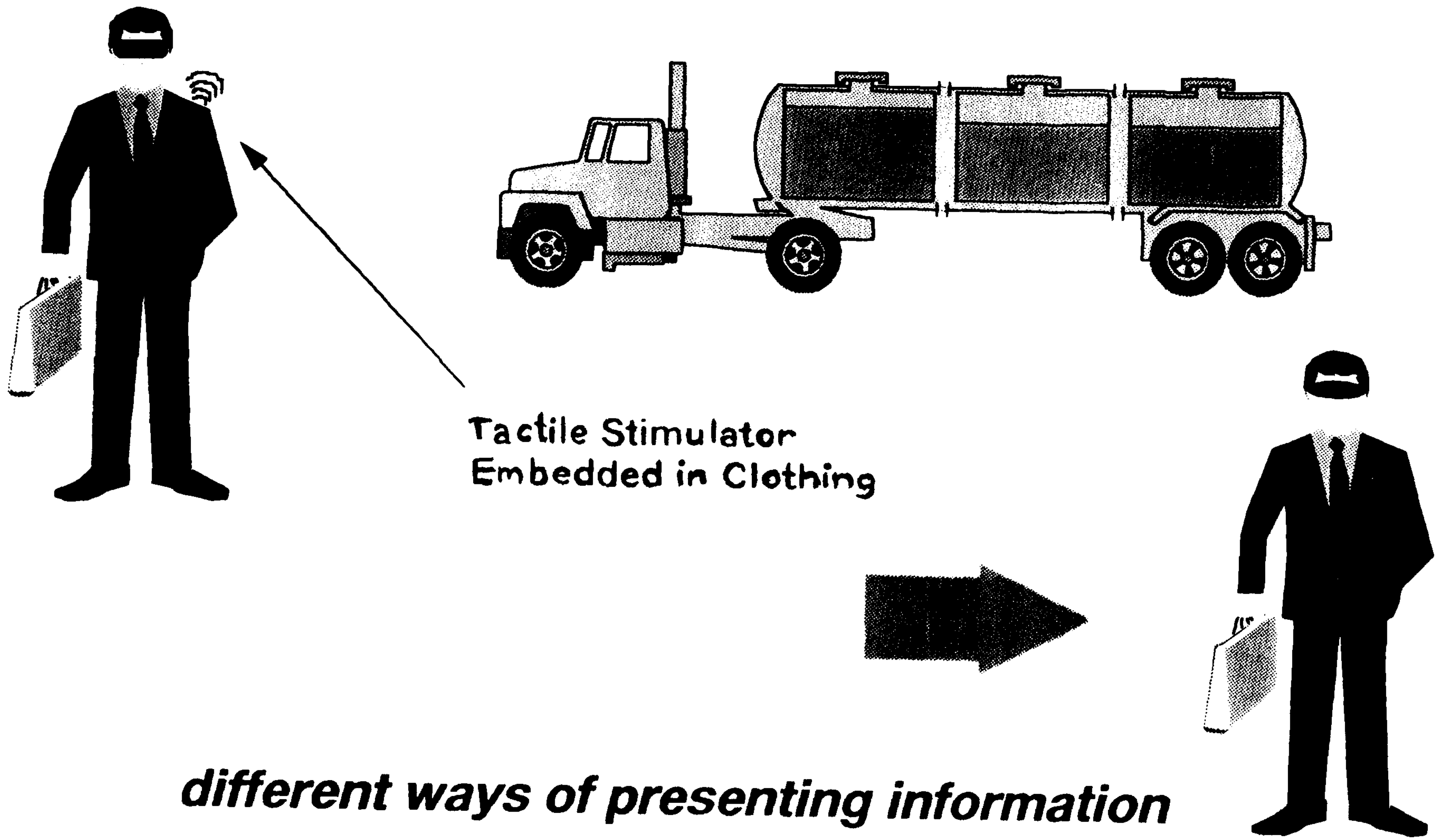
Tactile displays

Kinesthetic Feedback

Inappropriate Visual Displays

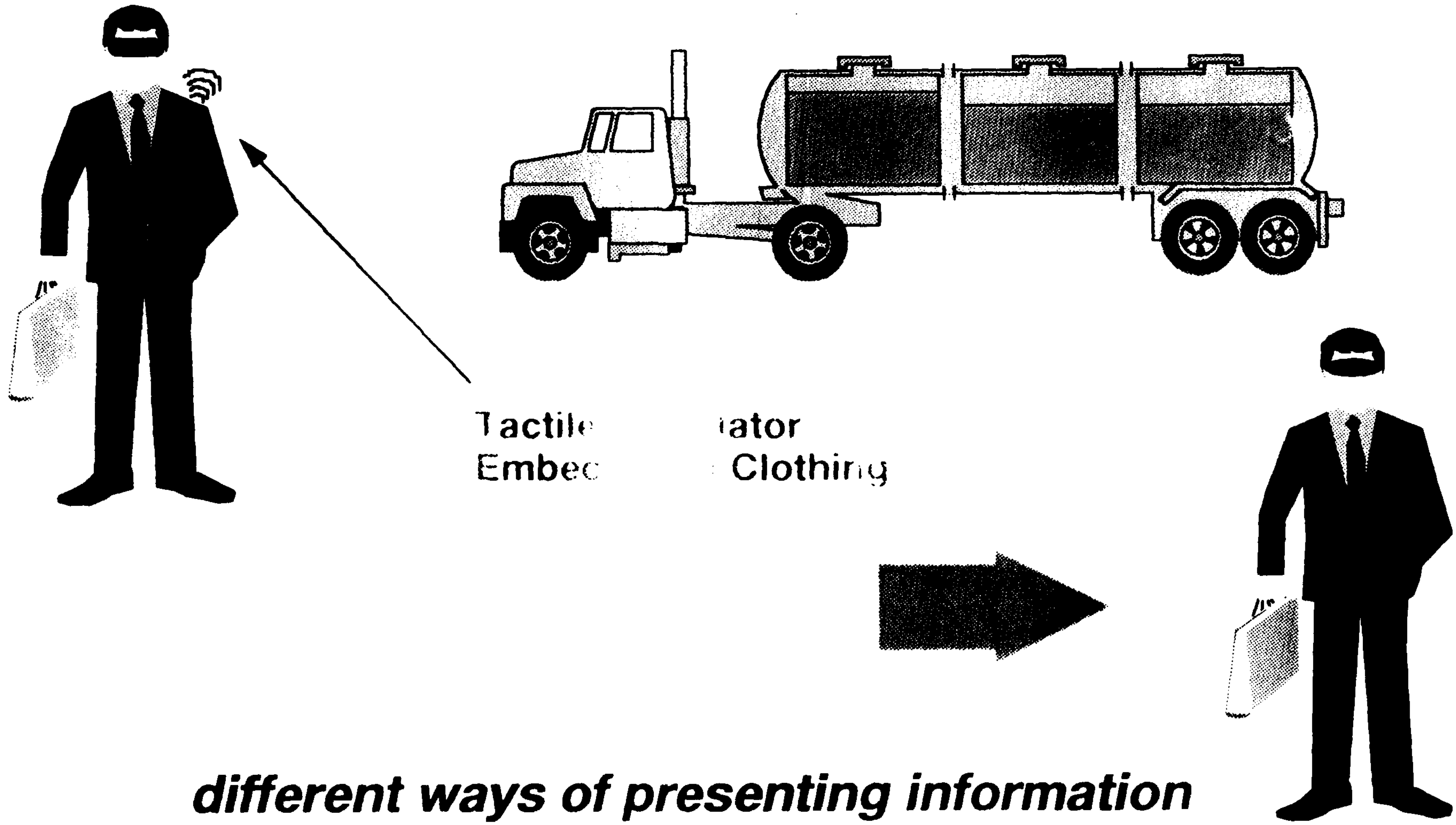


Tactile/Kinesthetic Displays



different ways of presenting information

Tactile/Kinesthetic Displays

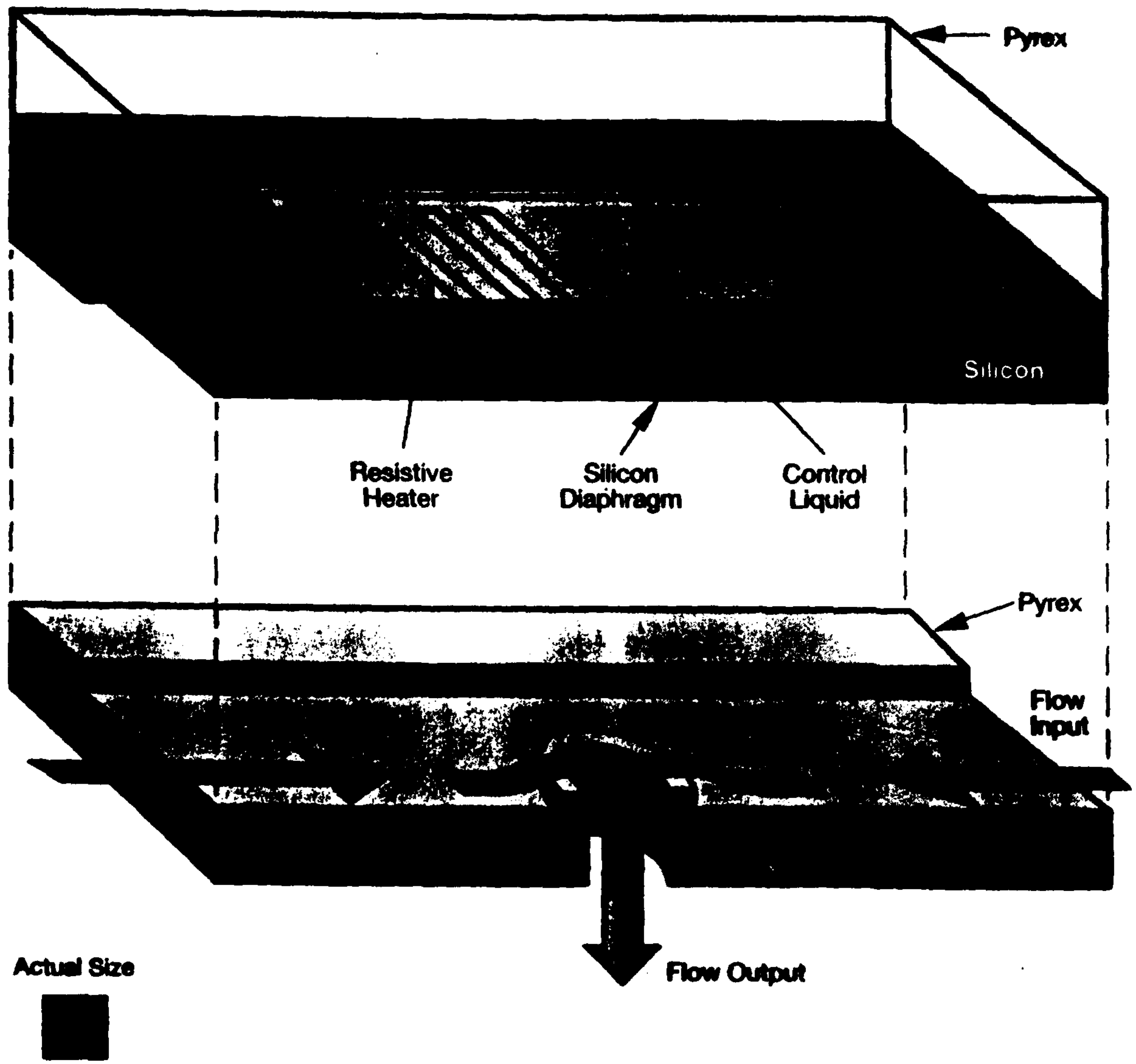


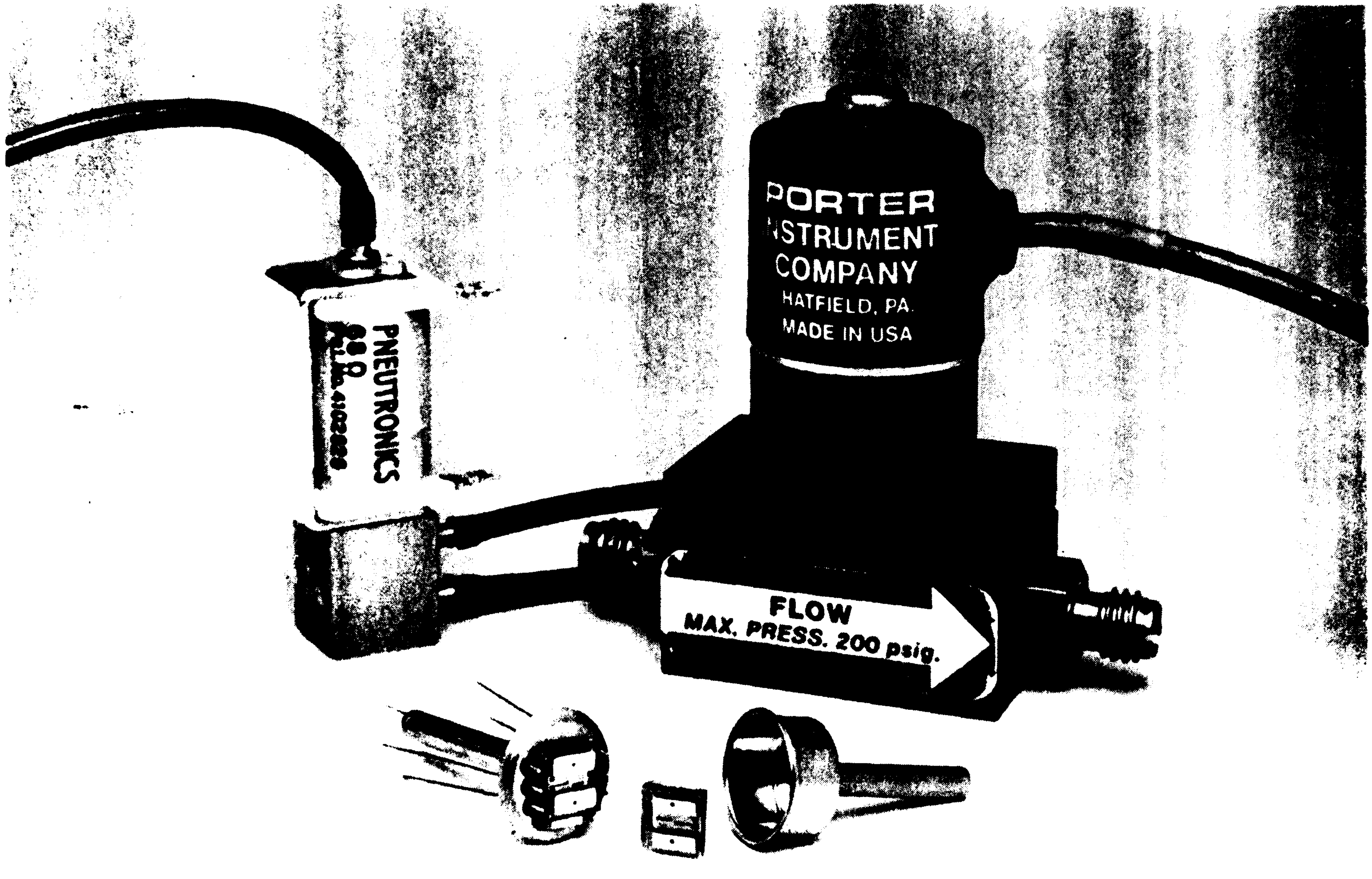
different ways of presenting information

Redwood Microsystems Flow-Valve

In the same way that MEMS enable revolutionary advances in sensing, MEMS will enable increased control over the enviroment. MEMS will increase the number and type of actuators, providing the converse functionality of information gathering. MEMS is as much a revolution in the way we make electromechanical systems as it is a revolution in the size of electromechanical systems. The three key aspects of MEMS are **miniaturization, multiplicity** and **microelectronics**. MEMS will enable monolithic sensors, actuators and electronics all integrated on the same substrate and fabricated using the same processes. This integration will lead to improved and new functionality including self-calibration, self-testing and the ability to progamm operational characteristic after fabrication. In addition, the multiplicity inherent in the VLSI fabrication allows for alternative design approaches that are impractical to achieve in the macro domain. As an example of

THE FLUISTOR™

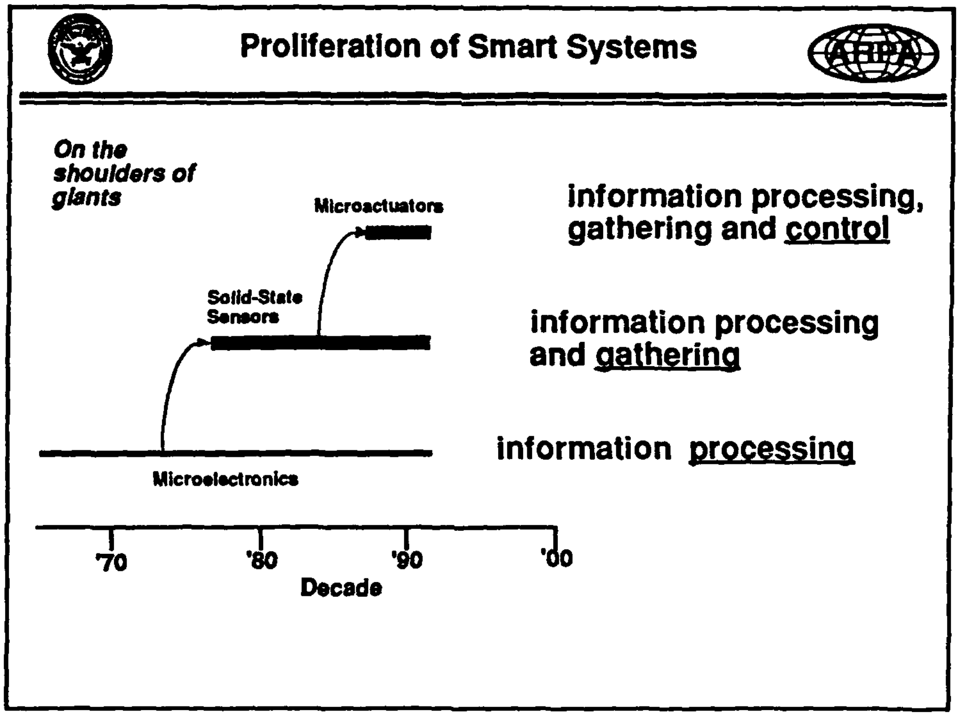



PORTER
INSTRUMENT
COMPANY
HATFIELD, PA.
MADE IN USA
FLOW
MAX. PRESS. 200 psig.
PNEUTRONICS

TI Micromirror Display

An excellent example of the new type of electromechanical systems design enabled by MEMS is the TI micro mirror display. The MEMS device is the heart of a high-definition projection display systems. The device is made up of over 2 million micro mirrors, each of which correspond to one pixel on the display. Each mirror is 17 microns by 17 microns on a side and is suspended by flexural support beams on two of the diagonal corners. When an electrostatic voltage is applied to an electrode underneath the mirrors, the mirror rotates about the suspension. The deformed mirror deflects light into the condensing optics and the corresponding pixel is on. By oscillating the mirror deflections and varying the duty cycle of the deflection, gray-scale illumination is achieved. By synchronizing the deformations with a color filter, registered color displays are possible. The micromechanical mirrors are fabricated on top of an SRAM using a process compatible with the microelectronics fabrication. Each pixel is activated by loading a logical one in the corresponding memory location, with pixel addressing being implemented exactly as in SRAM addressing.

LOW-BANDWIDTH LARGE SCALE SYSTEMS SLIDE



The increased mobility, portability and miniaturization of information systems coupled with the increased capability and availability of miniature sensing and control devices will lead to an increase in both the numbers and affordability of both military and civilian smart systems.

III-H ULTRA DENSE, ULTRA FAST COMPUTING COMPONENTS

DR. JANE ALEXANDER

ADVANCED RESEARCH PROJECTS AGENCY
3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

June 16, 1993

MEMORANDUM FOR DSO - ALEXANDER

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

Reference is made to the following material submitted for clearance for open publication:

ULTRA DENSE, ULTRA FAST COMPUTING COMPONENTS PROGRAM

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G. T. Winn
Technical Information Officer

Attachments

Ultra Dense, Ultra Fast Computing Components Program

Jane A. Alexander

ARPA/MTO

(703) 696-2233

Presentation at ARPA Symposium

24 June 1993

#1

DSO Alexander

Presentation at the ARPA Symposium, 24 June 1993, Newport, Rhode Island - The Ultra Dense, Ultra Fast Computing Components Program

Slide # 1 - Title page

Slide #2 - Computation in the form of embedded processing or stand-alone computers is crucial to present and future military systems and to many commercial sector products. Intelligent personal electronics will increase the need for faster, cheaper, and higher density computation in the future.

Slide #3 - The military has many applications for which real-time computation needs exceed the capacity of systems with sufficiently small volume, weight, and power requirements. Among these applications are intelligence, signal processing, image analysis, signal analysis, and scenario modeling. Electronic components being developed under the Ultra program will address these computation needs.

Back to Slide #2 -Cost has been the major driver in reducing transistor size in the past. The trend has been for the cost to process a wafer to stay roughly constant with the shrinking size of devices. This shrinking of conventional devices has given us great advances in speed, density, and lower power.

However, shrinking conventional devices to stay on the performance growth curves has a limit. Now is the time to explore alternative technologies to produce fast, denser, higher functionality electronics. Both electronic and photonic concepts needed to be developed. This is what the ARPA Ultra program is about.

Slide #4 - I know that you have heard in the past that the critical feature could not be reduced beyond 2 microns, 1 micron, or 0.25 micron. These arguments were and are primarily economic. The desired feature size was considered to be too expensive to produce until the needed technical breakthrough was made. The limit to conventional FETs which I am speaking about is a physics limit. As the critical feature size drops below 0.1 micron quantum effects become increasingly important and the device performance degrades.

93-S-2037

Slide #5 - The biggest problem for FET type devices in the sub-0.1 micron regime is subthreshold leakage. Cryogenics will help reduce this problem, but cryogenics requires additional power or a liquid cryogen, additional weight, and additional volume. For some applications this is fine, but for person-portable systems this is a severe limitation. Cryogenics for main frames is still an open question. The Ultra program is examining both room temperature operating devices and some cryogenic operating devices. In general the technology must be interoperable with conventional technology (voltages, temperatures) or offer sufficient advantage to warrant nonstandard operating conditions. Since cryogenics will only help conventional devices shrink a little further in size, we go back to basic physics to look for new devices to continue the performance and size advances.

As we look for new devices, we must keep in mind that the new technology must be manufacturable and affordable. Any new technology developed must becost competitive with the best silicon components of the future. Since there is a large investment in silicon processing equipment and considerable knowledge about these materials, we must examine whether there is a way to leverage existing silicon technology. Another issue to consider is that most of the new devices proposed are not identical to conventional transistors in their operating characteristics. This means that the technology community must examine and optimize circuit architectures to take advantage of the new devices.

Slide #6 - The ARPA Ultra program has two main objectives: (1)to develop ultra dense, ultra fast electronic and optical components for future generation computing and (2) to develop fabrication technology for these components. The ULTRA program is a basic research program exploring new concepts for computation devices and circuits. The ULTRA program is not intended to incrementally improve conventional electronics, but rather to explore and demonstrate concepts for taking electronics beyond the functionality and density that conventional electronics can reach through size reduction.

Slide #7 - Ultra is the most long range of the ARPA electronics programs. It pushes new concepts for electronic and photonic devices and fabrication processes beyond what the SEMATECH, Advanced Lithography Program, TOPS, and Photonics Program do.

Slide #8 - I have challenged the device and circuits community to create and optimize new devices which are tolerant of imperfect manufacturing. Some new device concepts require that each device be made perfect, without any scattering centers. Devices of this type may have interesting physics, but will not make good technology. Ultra is a basic research program aimed at developing technology. The second challenge that I have made is to the fabrication community to be able to fabricate perfectly on the nanometer scale.

Slide # 9 -
DARPA is sponsoring innovative research in the following 5 areas:
(1) Terabit Memory Technology - Seminal approaches for ultradense memories, including optical, optoelectronic, electronic, and micromechanical approaches and/or their combinations. Research concepts which will lead in the next stage to the development of terabit or greater density memories is the thrust. The goal is a read/write memory with unlimited endurance, terabit in a cm^2 or cm^3, and extremely rapid access times.

2) Nanoelectronics - Invention and exploration of novel electronic quantum devices and circuit architectures including, but not limited to, resonant tunneling diodes and resonant tunneling transistors. Combinations of quantum devices with conventional transistors are acceptable if the resulting circuit has a significantly improved functional density over conventional electronics. The device's capabilities are explored in circuits in addition to individual device performance.

3) Optical Computing - Concepts to extend the capabilities and functionalities of optical interconnects through the use of optical logic. Included in this area are new architectures for novel chip, module, and computer designs that are enabled by optical or optoelectronic technologies. In addition to the long term goal of an all-optical, free space computer, a highly intelligent optical interconnect providing connectivity among highly parallel, low cost processors is to be pursued.

4) Interconnects and I/O - Devices, components, and processing technologies that allow integration of optical and optoelectronic interconnects and I/Os. Included in this area are 1D arrays, 2D arrays, 3D assemblies, and wavelength mux/demux concepts that are integrable,

extendable, and scalable. Device packaging and reliability issues are to be emphasized. Simplified optoelectronic interfaces for optimal conversion of data/signal between optical and electrical domains are being investigated.

(5) Nanofabrication/nanotechnology - This area includes all of the base technology for design, fabrication, and test in support of the above 4 areas, including, but not limited to: process modeling for optoelectronic structures and electronic semiconductor heterostructures; selective area deposition; selective and anisotropic etching; selective doping; control of abrupt interfaces, reproducible growth of heterostructures with minimal variation over the wafer; 3-dimensional pattern definition; integration of dissimilar materials; and high speed measurement and test. Fabrication techniques to be explored must be extendable to the development of low-cost realistic manufacturing equipment. A subsequent phase of the Ultra program will draw from this work to develop low cost, flexible manufacturing tools to build components.

Slide #10 - The Ultra program is exploratory in nature. Devices using any materials systems is allowed as long as there is a realistic way to fabricate them.

Slide #11 - Earlier I brought up the question of whether silicon based nanoelectronics is possible. Most work has been done in the III-V system because of the great richness of lattice-matched bandgap engineering possible. The challenge is develop some of this type of flexibility using silicon substrates.

Slide #12 - The challenges in fabrication for nanoelectronics are: (1) cointegration of dissimilar materials, (2) patterning nanometer features in the vertical and horizontal directions, (3) high yield, high uniformity growth, and (4) development of flexible processes and low cost manufacturing equipment

Slide #13 - Most of the quantum devices such as resonant tunneling devices have the nanometer dimension made through controlling the growth direction. MBE and MOCVD need to be optimized for the monolayer control and composition control needed for nanoelectronics. Chemical self-assembly is a different approach to fabrication on the nanometer scale. This is an emerging technology.

Slide #14 - The Ultra program is exploring several device types, circuit architectures, and fabrication techniques. This slide lists major thrusts

Slide #15 - The Ultra program includes contractors from industry, universities, and National Labs. A wide range of expertise is included in the program. For nanoelectronics to succeed, multi-disciplinary efforts are needed.

Slide #16 - The Ultra program aims for major advances in computation system performance, not just incremental improvement.

Slide #17 & 18- I would like to finish with a few highlights from the Ultra program. Texas Instruments has been able to produce a large increase in functional density of logic gates using resonant tunneling devices

Slides #19-24 - Stanford University is developing a nanoprobe. This is an atomic force microscope modified to sample the voltage with extremely low capacitive loading of the circuit. The instrument resolution should be better than 50 nanometers with a temporal resolution better than a picosecond.

Slides #25-27 - Naval Research Laboratory is developing nanochannel glass. This material is similar to that in quartz channel plates except the glasses are being optimized for hole diameters down to 5 nanometers. The nanochannel glass has applications in deposition and patterning of nanostructures.

Slides #28-29 - Yale University and the University of South Carolina are developing self-assembled molecular wires.

Slide #30 - The University of Illinois has developed e-beam resists of oxide films capable of producing 5 nanometers holes on 8 nanometer centers.

Slide #31 - CalTech has developed an artificial retinue using resonant tunneling devices. The edge detector is implemented in far fewer devices than is possible in conventional silicon technology.

ULTRA DENSE, ULTRA FAST COMPUTING COMPONENTS

- COMPUTERS ARE THE HEART OF PRESENT AND FUTURE MILITARY SYSTEMS.
- ADVANCES IN SPEED, DENSITY AND LOWER POWER REQUIREMENTS HAVE BEEN DRIVEN BY SHRINKING CONVENTIONAL DEVICES, TRANSISTORS AND INTERCONNECTS
- HOWEVER, CONVENTIONAL SCALING WILL HIT A WALL SOON.
- OPTOELECTRONICS, NANOELECTRONICS, AND THEIR COMBINATION OFFER ULTRA DENSE, ULTRA FAST, HIGHER FUNCTIONALITY ELECTRONICS

#2

MILITARY PAYOFF

- REAL TIME COMPUTATION FOR:
  - INTELLIGENCE
  - SIGNAL PROCESSING
  - IMAGE ANALYSIS
  - SIGNAL ANALYSIS
  - SCENARIO MODELING

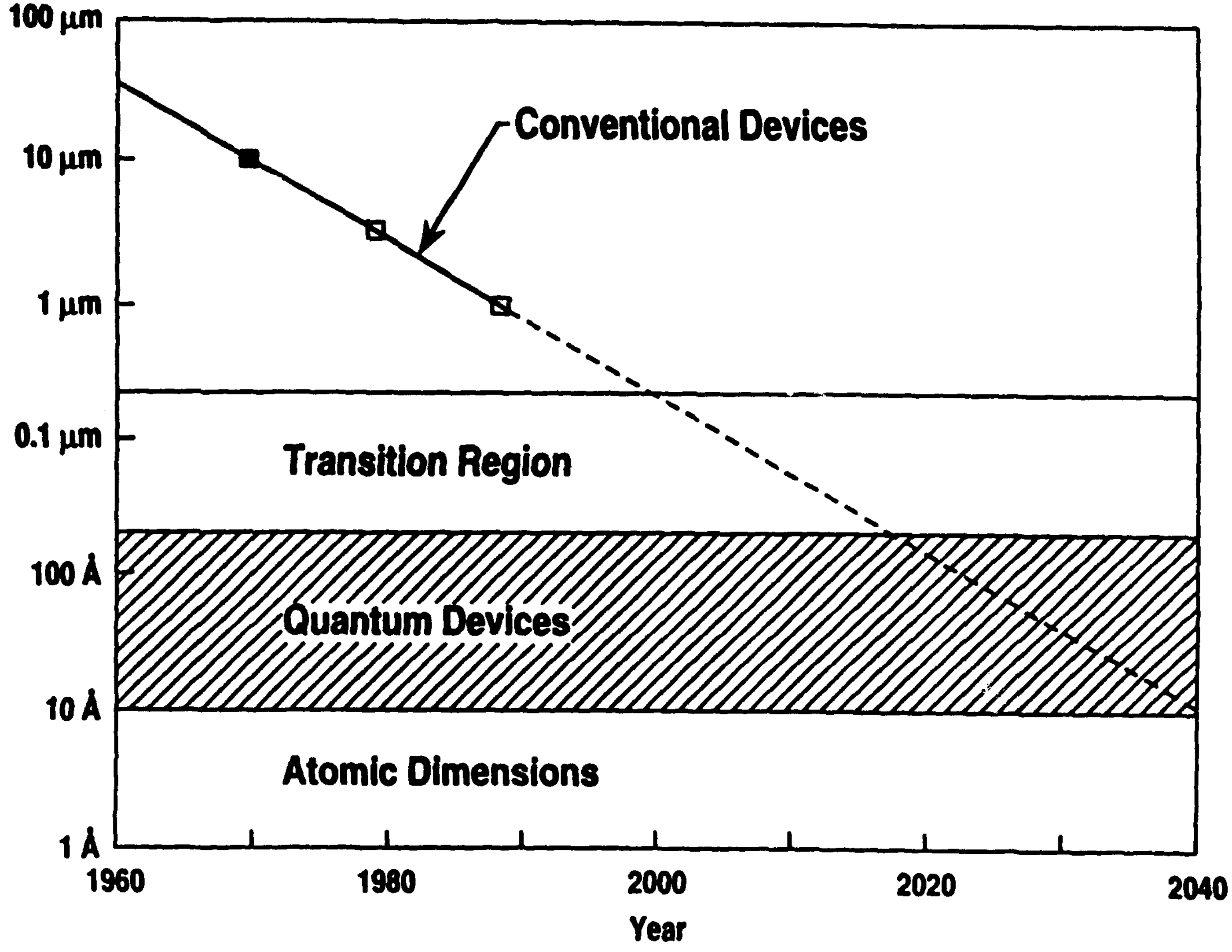
- SMALLER POWER REQUIREMENTS/HIGHER PERFORMANCE FOR ALL EMBEDDED APPLICATIONS

- GREATER ROBUSTNESS, SMALLER SIZE, LOWER COST

- GREATER IMMUNITY TO INTERFERENCE, JAMMING, AND ELECTRONICS UPSET AND BURNOUT

#3

DEVICE SIZE



#4

ELECTRONICS OVERVIEW

- Limit for Scaling Below 0.1 μm is Subthreshold Leakage
- Cryogenics Helps, <u>but</u> Limited Application
- Solution is Physics, e.g., Tunnel Barrier Device
- Driven by Cost—
  Can we leverage existing Si technology?
- Interconnects and Circuit Architectures are Issues

#5

OBJECTIVES OF THE ULTRA PROGRAM

- TO DEVELOP ULTRA DENSE, ULTRA FAST ELECTRONIC AND OPTICAL COMPONENTS FOR FUTURE GENERATION COMPUTING

- TO DEVELOP FABRICATION TECHNOLOGY FOR THESE COMPONENTS

#6

TIMELINE

SEMATECH / SRC - Next generation silicon

Advanced Lithography Program / MMST -
Next and future generation silicon

Photonics Program / TOPS -
Next and future generation use of optoelectronics
Generally gallium arsenide based

ULTRA Program - new devices and architectures
Combining electronics and photonics
Using silicon, gallium arsenide, and other materials
Pushing beyond the limits of present technologies

#7

TECHNICAL GOALS

Devices and Circuits:

- Explore New Types of Devices and Their Functionality in Circuits
- Push for Fault Tolerant Devices and Circuit Architectures

Fabrication:

- Develop Fabrication Capabilities With Atomic Control

#8

PROGRAM THRUSTS

- Nanoelectronics
- Terabit Memory
- Interconnect and I/O
- Optoelectronic and Optical Computing
- Nanotechnology/Fabrication

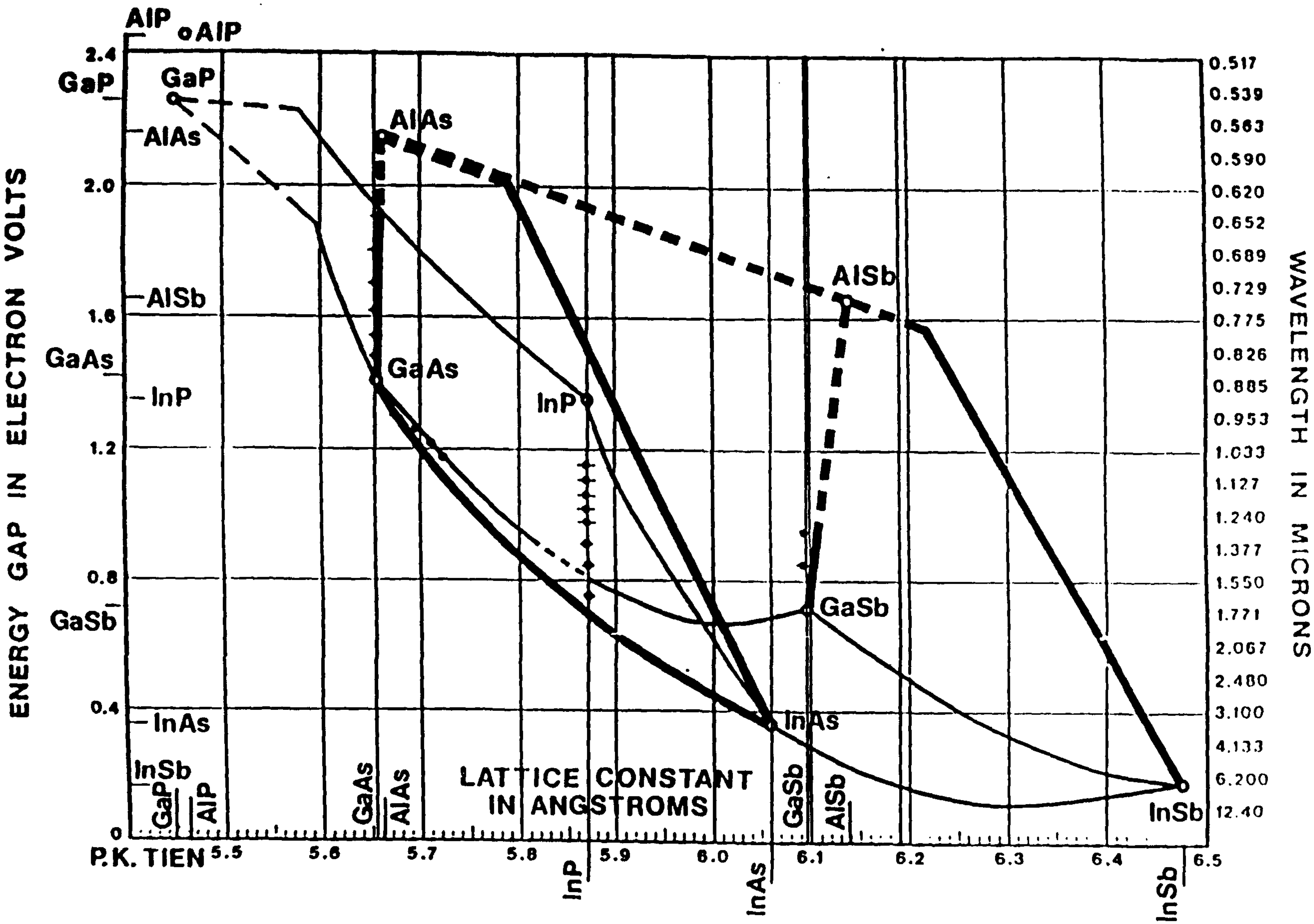
#9

APPROACH

USING THE BEST OF EACH TECHNOLOGY

GaAs/AlGaAs and other heterostructures	Si
Optoelectronics	Organics
Photorefractive	Ferroelectric

#10


ENERGY GAP IN ELECTRON VOLTS
WAVELENGTH IN MICRONS
LATTICE CONSTANT IN ANGSTROMS
2.4
2.0
1.6
1.2
0.8
0.4
0
0.517
0.539
0.563
0.590
0.620
0.652
0.689
0.729
0.775
0.826
0.885
0.953
1.033
1.127
1.240
1.377
1.550
1.771
2.067
2.480
3.100
4.133
6.200
12.40
5.5
5.6
5.7
5.8
5.9
6.0
6.1
6.2
6.3
6.4
6.5
AlP
GaP
AlAs
AlSb
GaAs
InP
GaSb
InAs
InSb
P.K. TIEN

FABRICATION ISSUES

- Cointegration of Dissimilar Materials
- Patterning Small Features in 3-Dimensions
- High Yield, High Uniformity Growth
- Development of Flexible Processes and Low Cost Equipment

#12

FABRICATION

- Chemical Assembly Techniques for Nanostructure Control

- Improved MBE and MOCVD Growth
  - In-Situ Monitoring and Feedback Control
  - Capable of Monolayer Control, Monolayer Thickness Variation Across Wafer, Composition Control Including Grading

#13

EXPANDED ULTRA ELECTRONICS THRUSTS

Resonant Tunneling (RT) Devices

RT Devices Combined with Conventional Devices

Quantum Dots

Multilevel Logic

Cellular Automata

Nanomagnetics

Single Electron Transistors and Logic

Electron Beam and Ion Beam

Self-Assembled Monolayers and Structures

#14

CONTRACTOR BASE

UNIVERSITIES

INDUSTRY

NATIONAL LABS

DEVICES

CIRCUITS

SYSTEMS

FABRICATION TECHNOLOGY

MANUFACTURERS

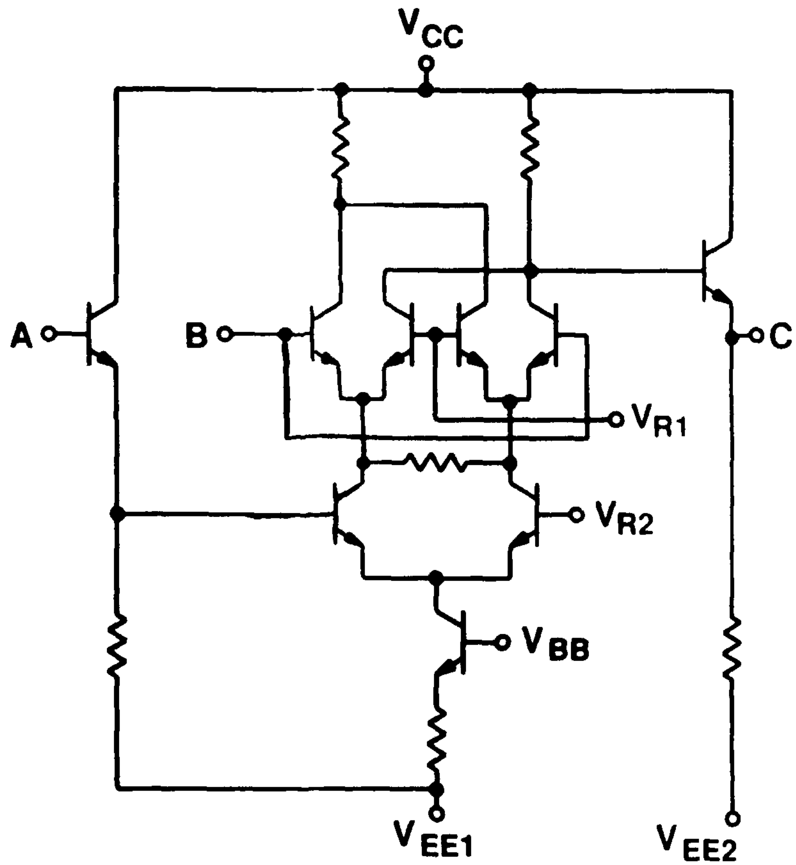
#15

TECHNOLOGY IMPACT
2010 VS 1990

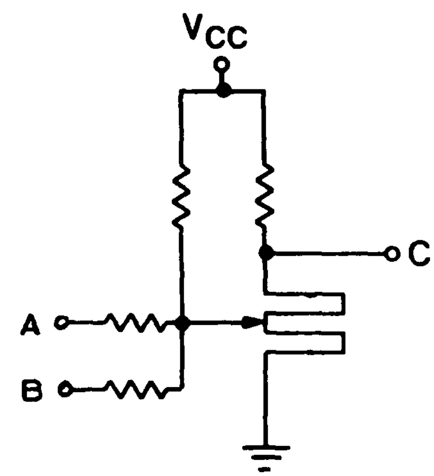
10,000 X INCREASE IN SYSTEM THROUGHPUT

- 10,000 X INCREASE IN SPEED OF INTERCONNECTION
- 100-1000 X FASTER SWITCHING SPEED
- 10-1000 X DENSER MEMORY AND LOGIC CIRCUITS

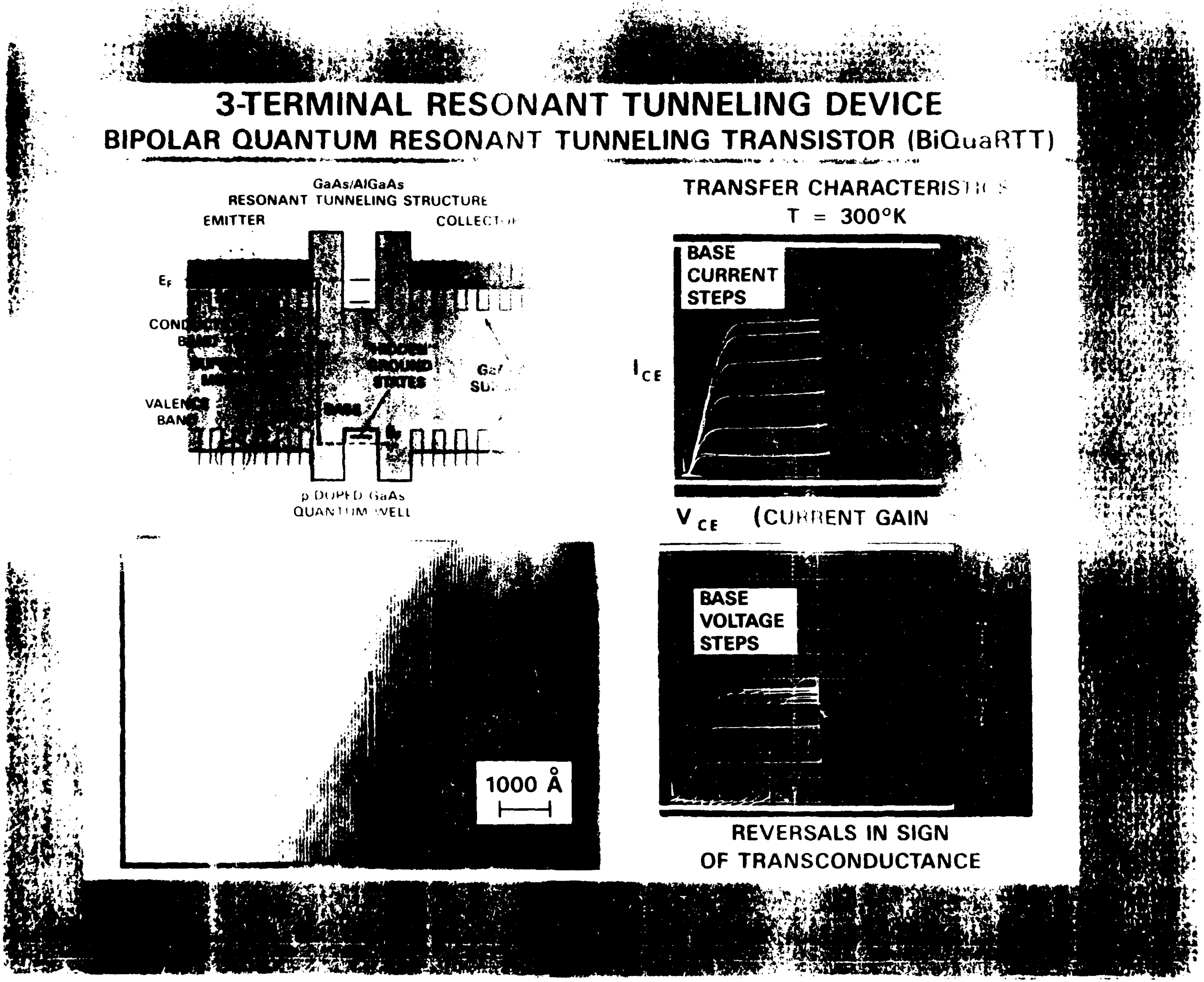
RESONANT - TUNNELING TRANSISTOR COMPRESSED - FUNCTION LOGIC



BIPOLAR EXCLUSIVE NOR
(9 Transistors)



SINGLE RTT
EXCLUSIVE - NOR


3-TERMINAL RESONANT TUNNELING DEVICE
BIPOLAR QUANTUM RESONANT TUNNELING TRANSISTOR (BiQuaRTT)
GaAs/AlGaAs
RESONANT TUNNELING STRUCTURE
EMITTER
E_F
VALENCE BAND
p DOPED GaAs
QUANTUM WELL
TRANSFER CHARACTERISTICS
T = 300°K
BASE CURRENT STEPS
I_{CE}
V_{CE}
(CURRENT GAIN
BASE VOLTAGE STEPS
1000 Å
REVERSALS IN SIGN
OF TRANSCONDUCTANCE

Scanning Force Microscope Samplers

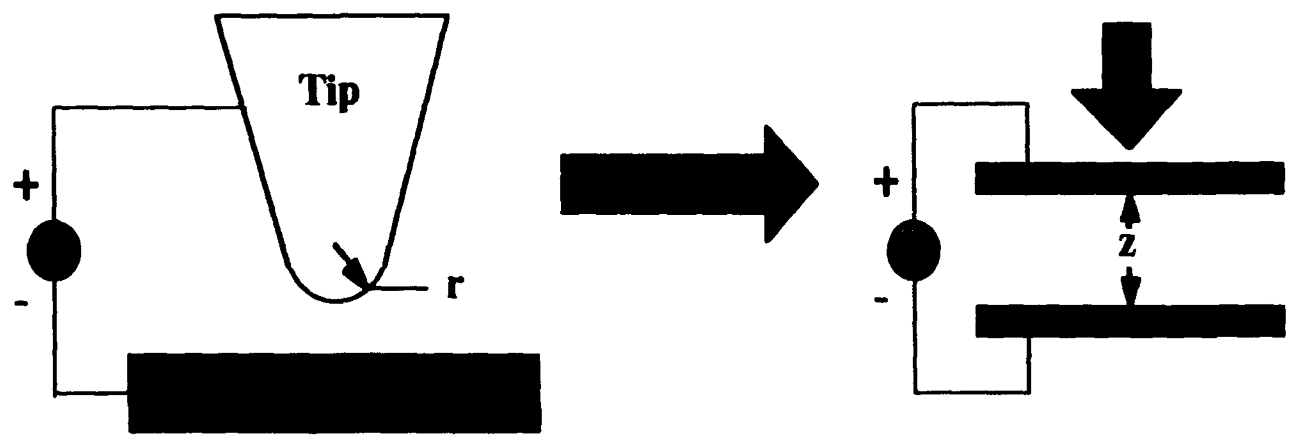
- Can potentially perform measurements with subpicosecond and submicron resolution
    - Spatial resolution is limited by tip dimensions (< 500 Angstroms)
    - Temporal resolution is limited by pulse width of sampling signal (< 1 picosecond)
- Noninvasive, ambient operation

Nonlinearity in Capacitive Force Produces Mixing

Tip-Sample System Equivalent To a Parallel Plate Capacitor With Effective Area $A = 2\pi r^2$

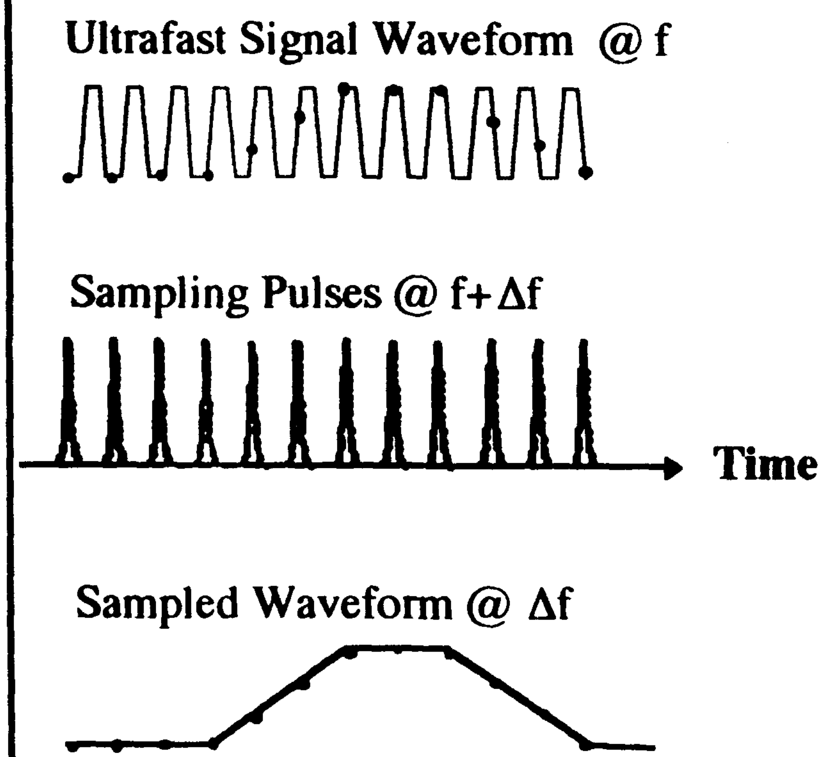
Square-Law Voltage Dependence Produces Mixing

$$\frac{\text{Force}}{\text{Area}} = -\frac{\varepsilon_0 V^2}{2z^2}$$



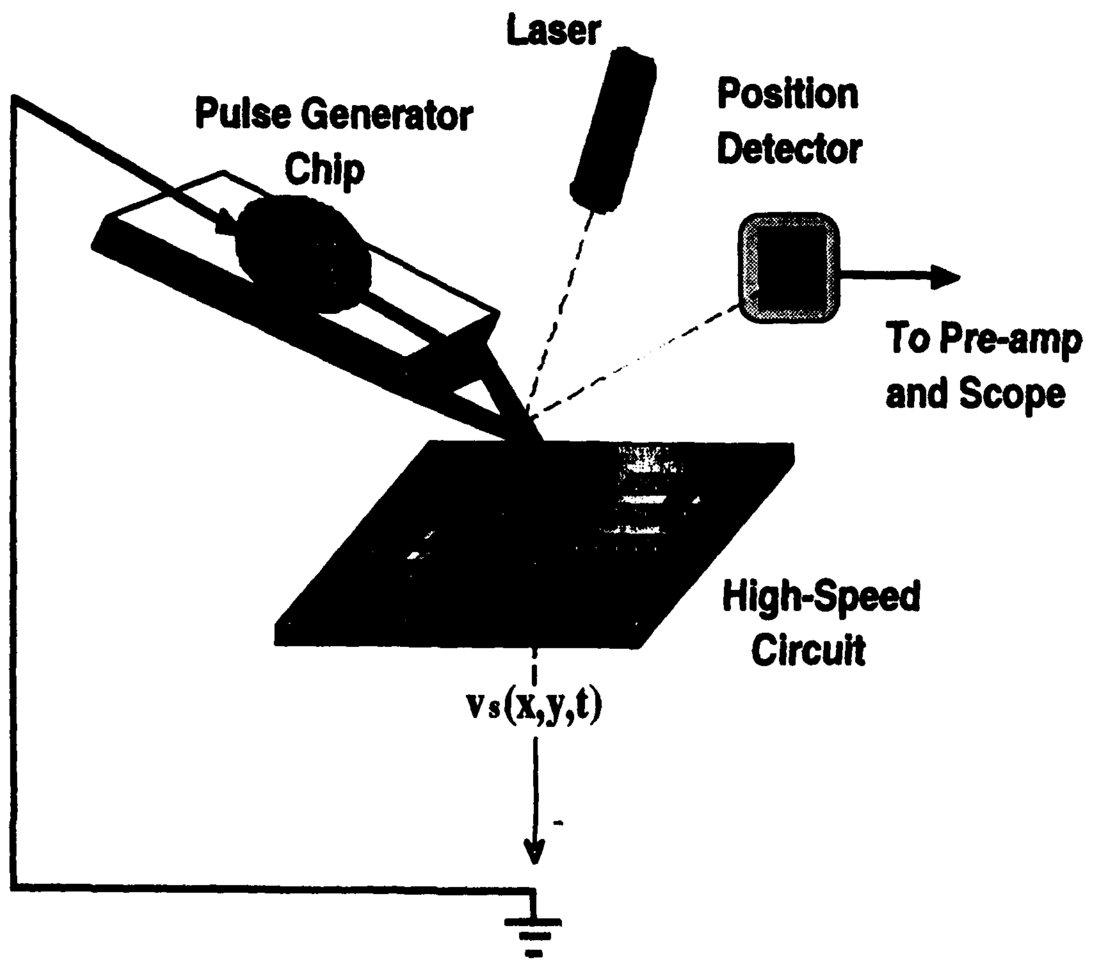
Parallel Plate Capacitor With Area A

Equivalent-Time Sampling



- In time domain, sampling is a multiplication process
- In frequency, can be thought of as harmonic mixing (convolution)
- Measurement bandwidth depends on sampling pulse width
- Sampled waveform is at intermediate frequency Δf

Proposed SFM Sampling System

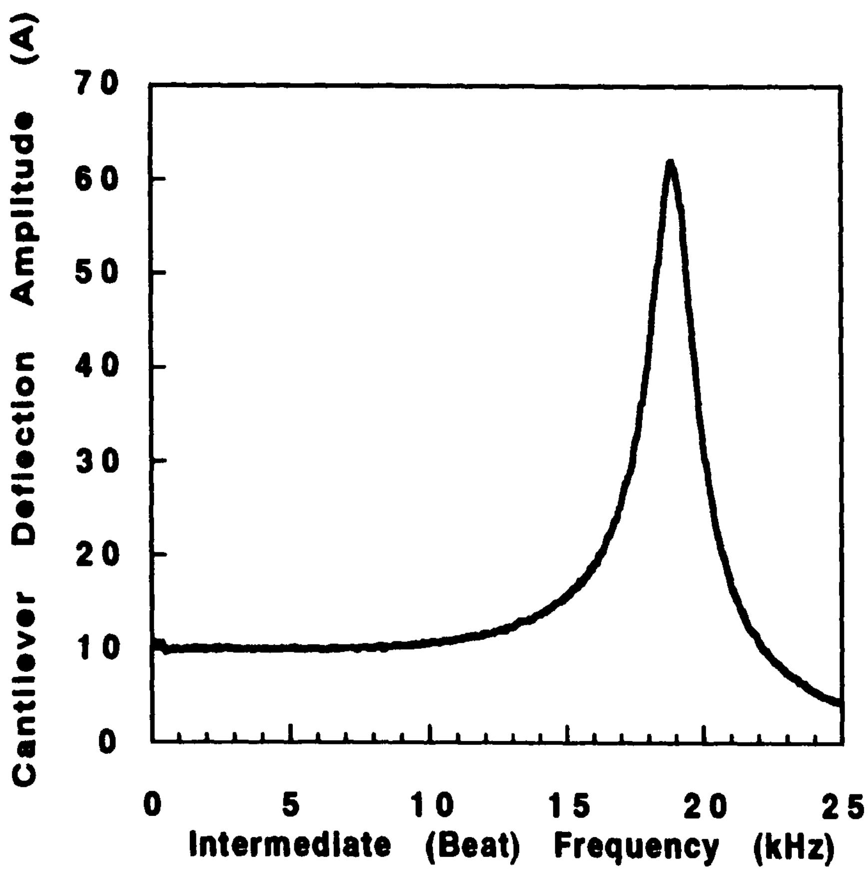


Approximate Dimensions

Tip Radius:	$r \sim 500$ Angstroms
Effective Tip Area:	$A \sim 0.01\ \mu m^2$
Separation Height:	$z \sim 100$ Angstroms
Capacitance:	$C \sim 0.01$ fF
Electric Force:	$F \sim 0.5\ nN/V^2$
Spring Constant:	$k \sim 0.05$ N/m
Cantilever Deflection:	$\Delta x \sim 100$ Angstroms/V^2

#23

High-Frequency Mixing

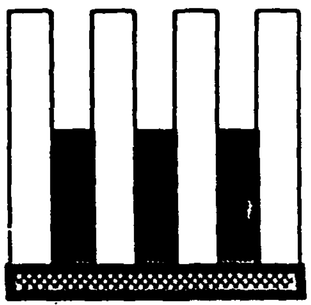


- Combined two sine waves at f and f + Δf
- Cantilever responds at beat frequency Δf
- Response shown for f = 1GHz, drive amplitudes of ≈ 1 Volt
- Similar results obtained up to 20 GHz, limited by package and input cable

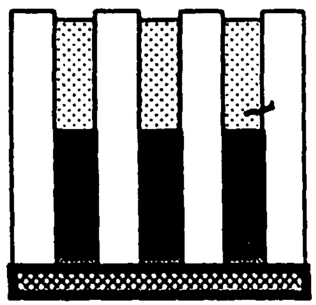
E. L. Ginzton Laboratory, Stanford University

More Complicated Configurations of Nanochannel Arrays

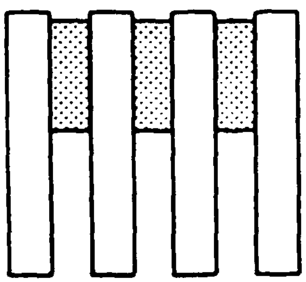
Channel Deposition With Dissimilar Materials



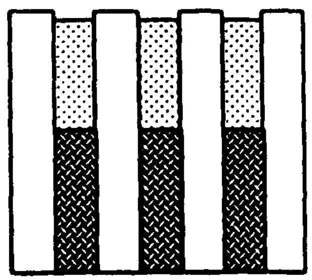
Nanochannel Array Etched With Protective Coating on Bottom



Material Deposited Into Empty Channels

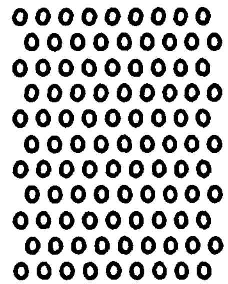


Protective Coating removed and Channels Etched

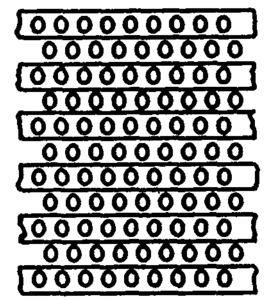


Deposition of New Material From Channel Array Bottom

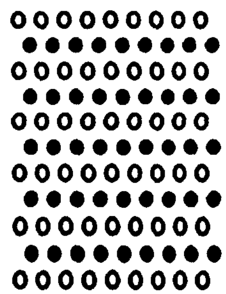
Channel Array Deposition By Dissimilar Materials



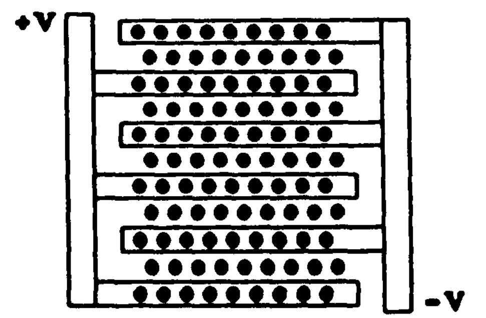
Nanochannel Array



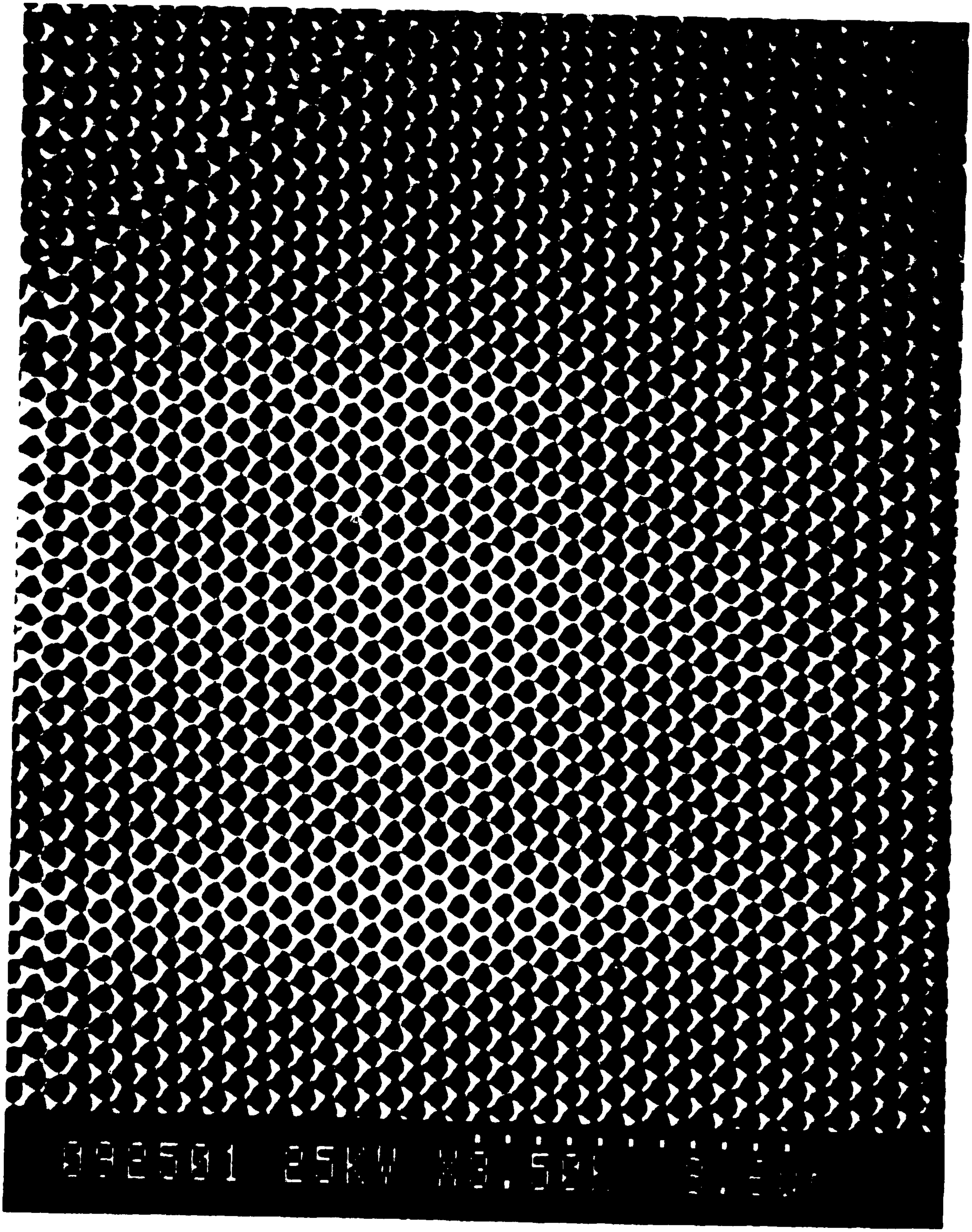
Protective Photoresist Strip Laid down on Alternating Rows of Channels



Etched Channels Filled With Semiconductor Materials After Resist Removal



Etching of Secondary Channels, Filled With Metal, and Contacts Added


092501 25KV

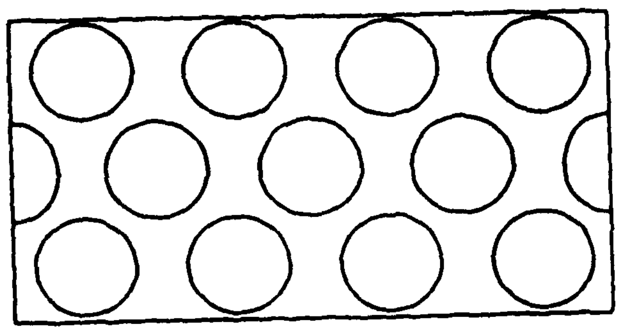
Nanochannel Glass Array Fabrication Technology

Rods of dissimilar glass are drawn under vacuum, reducing cross-section

Filaments are stacked clamped and redrawn several times

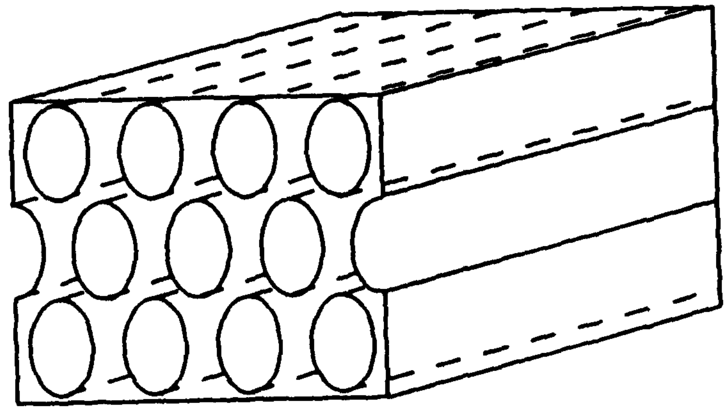
Magnified view

Acid treatment removes channel glass



Magnified view

3-D view



Magnified view

Yale Center for
Microelectronic Materials
and Structures

SPONTANEOUSLY-ASSEMBLED MOLECULAR TRANSISTORS AND CIRCUITS

OBJECTIVE

- Demonstrate electronic devices and circuits based on organic molecular structures

APPROACH

- Develop functional electronic devices and circuits from selective spontaneous attachment of synthetic conductive polymers
- Year 1: Demonstrate selective attachment of a single conjugated oligomer between nanofabricated metallic contacts

STATUS

- Synthesis of thiophene oligomers up to ~30Å has been achieved
- Synthesis of thiophene and phenylene oligomers with end group control has been achieved
- STM characterization tools are being developed
- Fabrication of sub-100Å contacts for selective attachment and electronic characterization defined and in progress

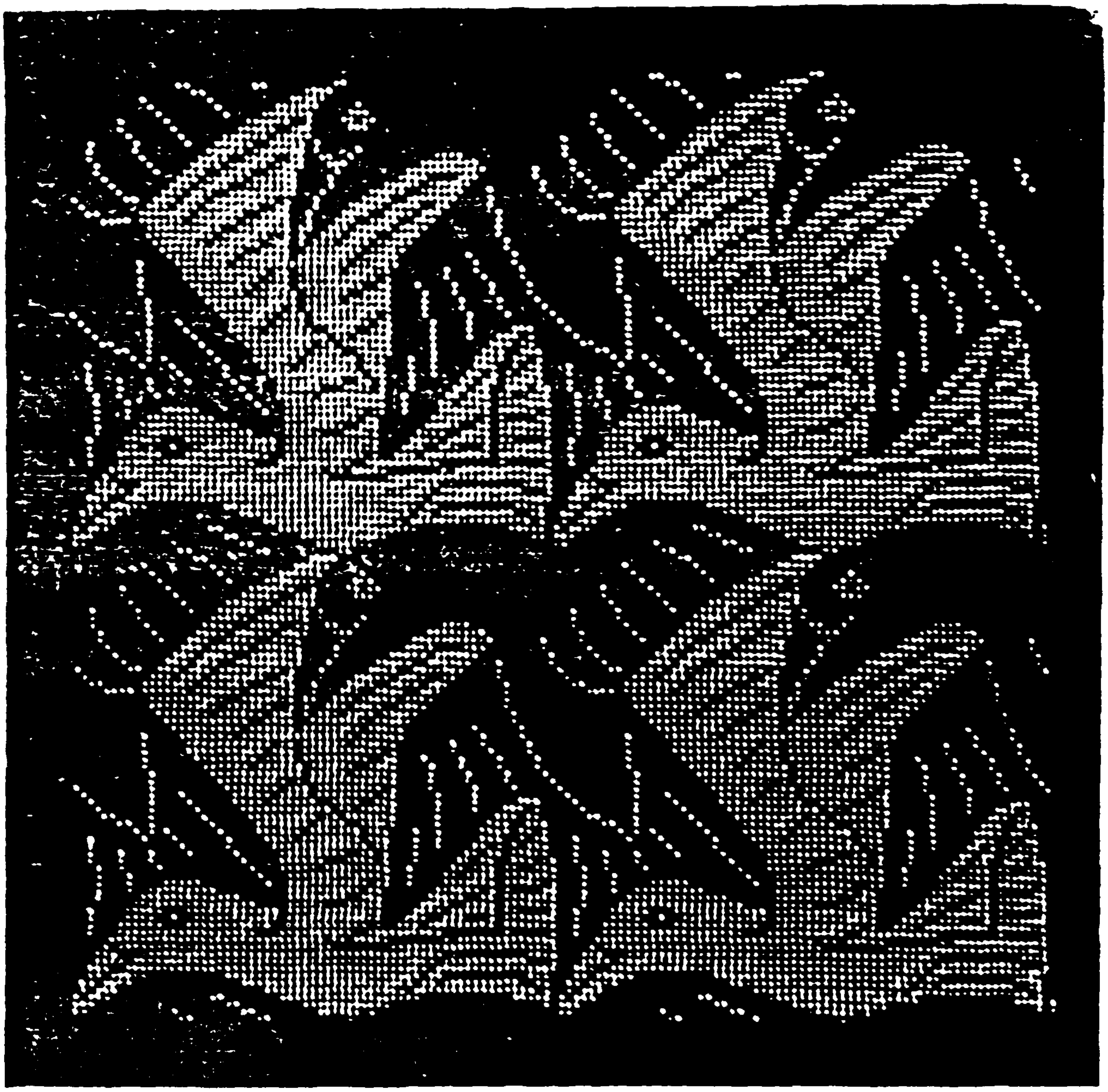
SCHEDULE

Year 1:

- Functionalize selective attachment structures onto oligomers
- Create ~100Å gap contact structures
- Synthesize ~100Å conjugated oligomers
- Develop STM/AFM characterization
- Model STM data, identify attachment candidates

#28

#30



1.0 μm

#31

NEW CONSORTIUM IN ULTRA ELECTRONICS

Ultra Dense Capacitor Materials Processing Partnership:

ATM, Micron, IBM, TI, AG (Started April 1993)

- High Dielectric Materials for Gbit DRAMs
- Focus on Barium Strontium Titanate
- Develop MOCVD Process and Equipment
- Develop Electrical Contact Structure
- Develop Patterning Capability

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Yale Center for
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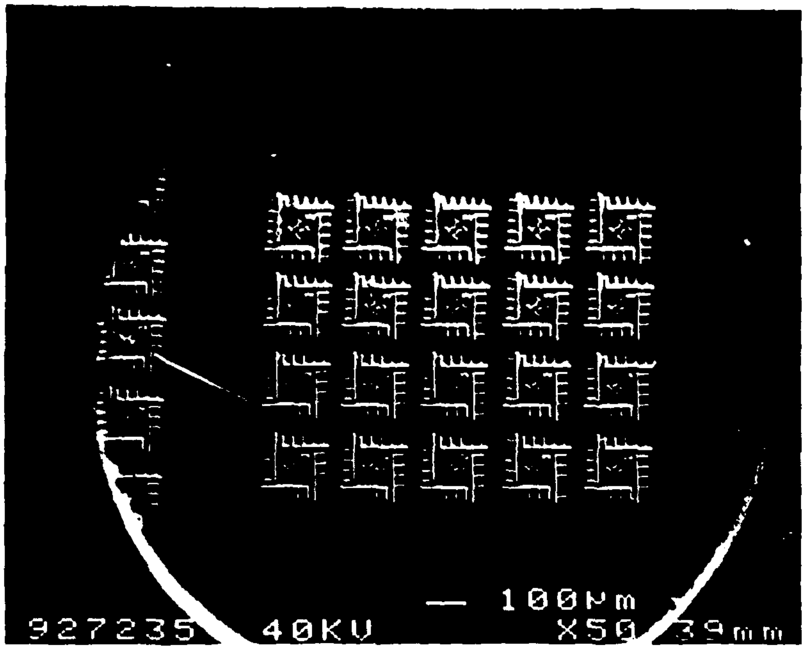
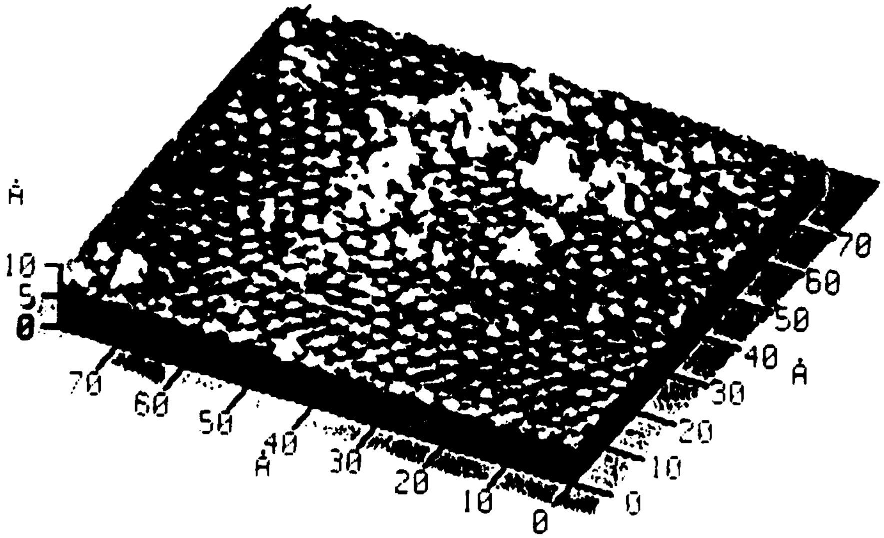
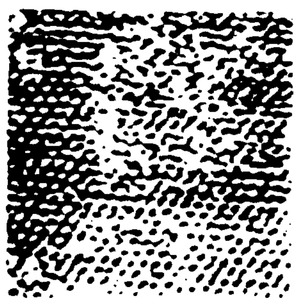


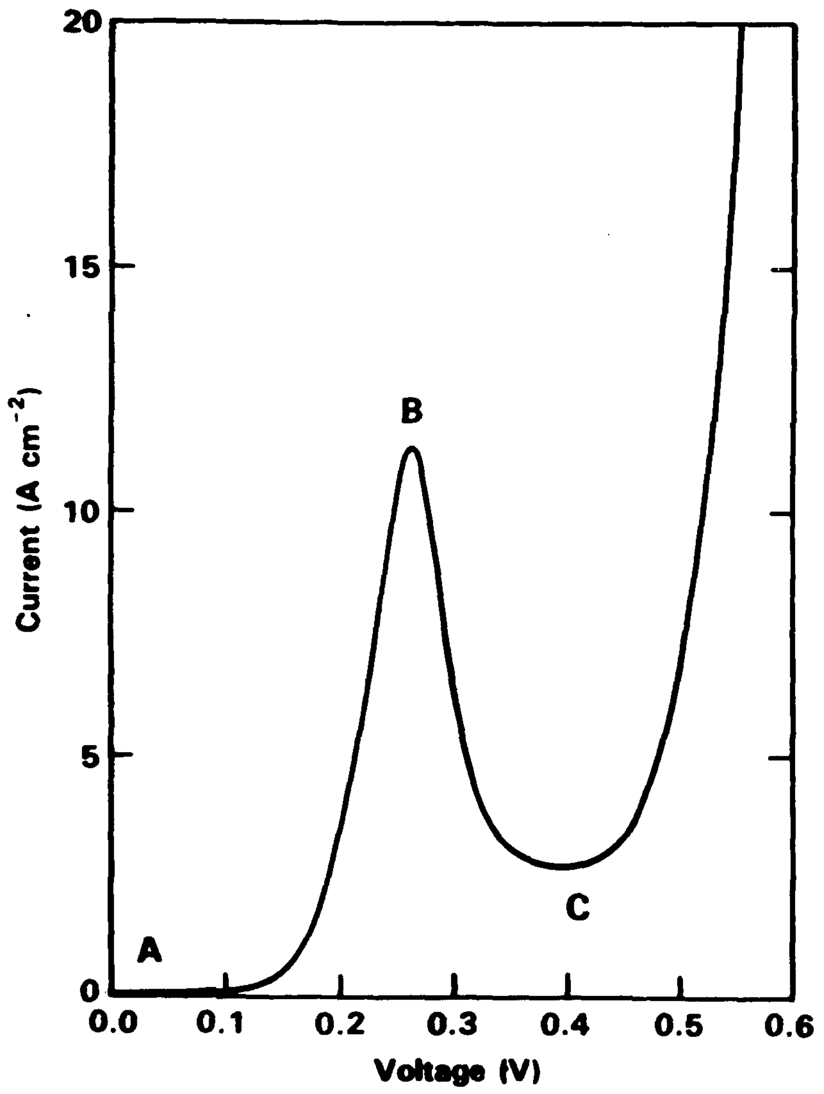
Electron beam lithography

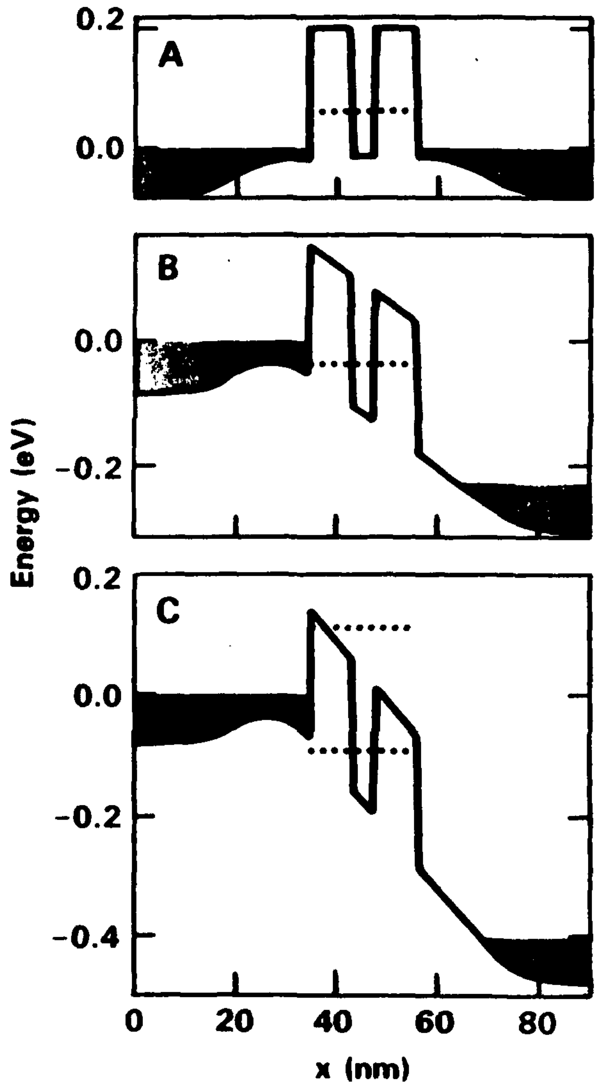




Ambient atomic resolution STM/AFM

RESONANT-TUNNELING DIODE





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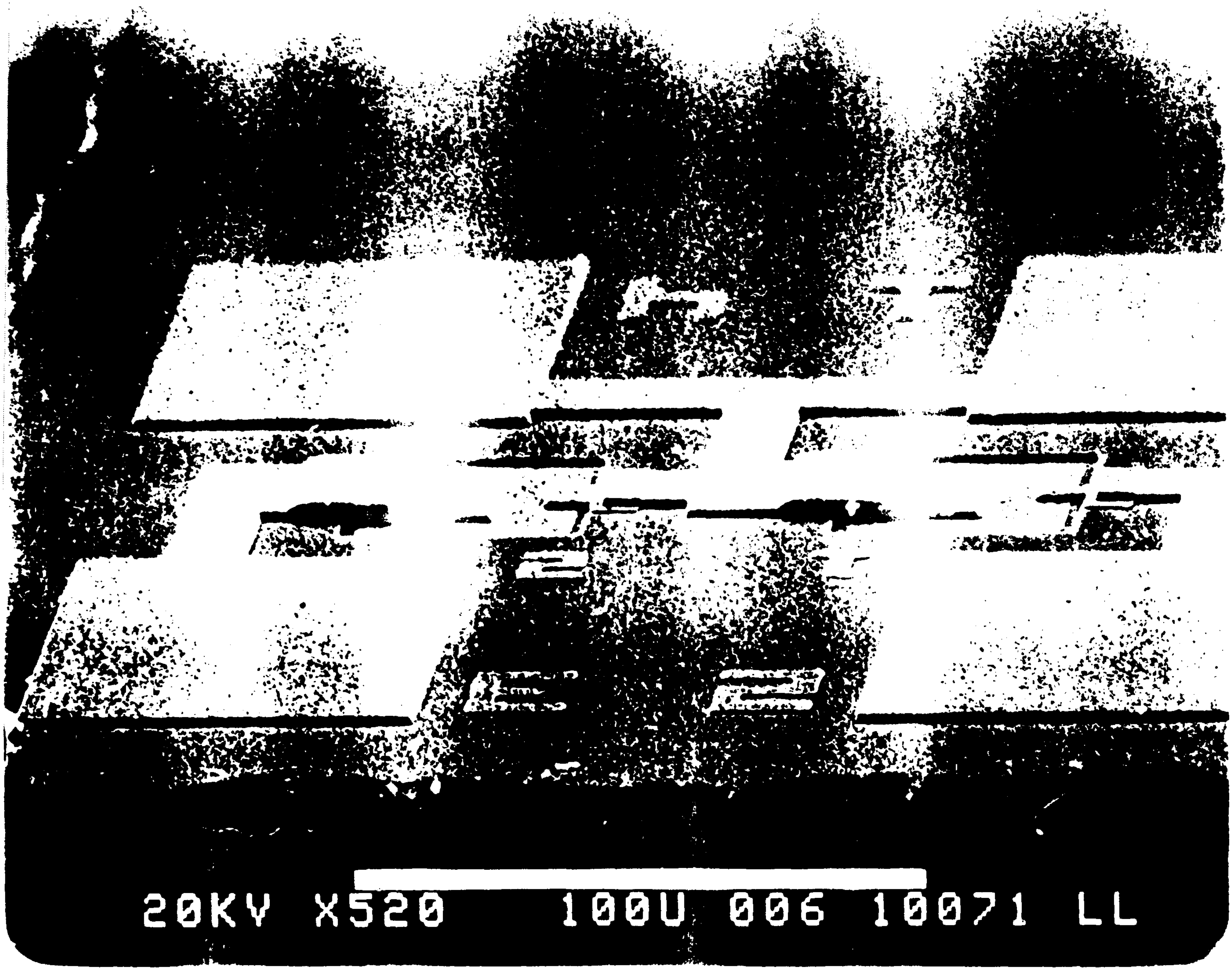
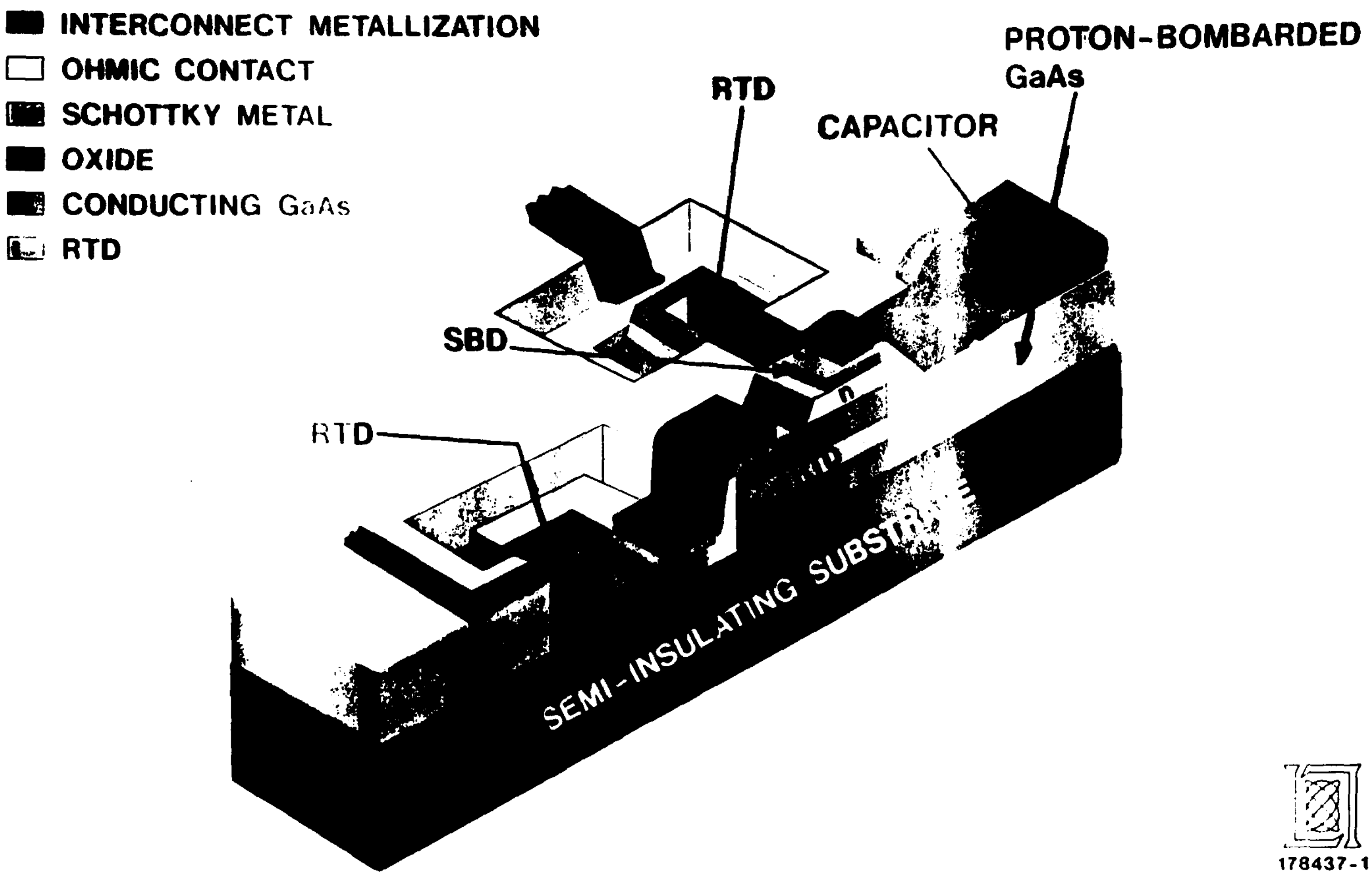


UNCLASSIFIED

RTD CIRCUIT PROJECTION



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KEYNOTE ADDRESS

K

HONORABLE WILLIAM J. PERRY, DEPUTY SECRETARY OF DEFENSE

Keynote Speaker
Dr. William Perry, Deputy Secretary of Defense

Wednesday, June 23, 1993
ARPA 16th Systems and Technology Symposium

Dr. Gary Denman, Director ARPA:

"It is my privilege to welcome our keynote speaker this afternoon, Dr. William Perry. Dr. Perry was appointed Deputy Secretary of Defense in March 1993. He returns to the DoD having served as the Director of Defense Research and Engineering from 1976 to 1981. He has extensive experience in the industrial sector including senior positions at Hamper and Quest, as well as senior position and founder of ESL. He serves on numerous advisory boards as a member of the National Academy of Engineering and a fellow of the American Academy of Arts and Sciences. Please give an ARPA welcome to the Honorable William Perry."

Dr. William Perry, Deputy Secretary of Defense:

"In consideration of the subject of this conference and ARPA being the sponsor of this conference, I decided to prepare my talk on around two related themes: technology and change. I would like to start by illustrating both of those themes. The first one comes from Dickens' *Martin Cheserwet:* "You have come to visit our country, sir, at a time of great depression', said the Major. 'At an alarming crisis', said the Colonel. 'At a time of unprecedented stagnation', said Mr. Jefferson Brick. 'Well, I'm sorry to hear that', said Martin, 'It's not likely to last, I hope'. 'Oh no', said the Major, 'I expect we should get along somehow and come right in the end.' 'We are an elastic country', said the Colonel. 'We are young lions', said Mr. Jefferson Brick. 'We have reviving and invigorating principles within ourselves', observed the Major." The invigorating and reviving principles we have within ourselves in this country, I believe, is technology. So my Dickens quote, which was not intended to be on technology by Dickens, is by me illustrating the technology theme. The second is a quote from John F. Kennedy, who said "Change is the law of life. And those who look only to the past or the present are certain to miss the future." Since its creation in 1958, ARPA has always looked to the future. I've always considered ARPA to be the crown jewels of the Defense Department because of its vision of the future and because of its creative and persistent exploitation of innovative ideas that take us into the future. The goal of this symposium, of course, is on the future and the objective is to give you some insight as to the potential futures in the Defense Department, particularly as concerns future defense technology. The future in the Department of Defense is not only being influenced by technology, it's being profoundly influenced by dramatic changes in the world environment, primarily as the result of the end of the Cold War. One manifestation of those changes is the very dramatic reduction in the defense budget. Our budget has already decreased 30 percent since its peak in 1986 in real terms and is likely to go to perhaps 40 percent decrease by the mid-1990s.

A manager's primary task is managing change. The most difficult and greatest challenge any manager faces is managing change brought about by reduction or downsizing. That's true whether you are managing an industry, university or Government. Managing downsizing is the most difficult challenge for a manager and historically, at least in the Defense Department, we always have gotten it wrong. After the second World War when we had a major downsizing, we managed it so poorly that five years after having the most powerful army in the world, we were almost thrown off the Greenland peninsula by an third rate country known as North Korea. After the Vietnam War and five years after we began that downsizing, we had what General Shomeyer called a "hollow army." And now we are trying to manage the downsizing after the end of the Cold War, and this time we are going to try to get it right. But history is against us and

psychology is against us and so we have to work very, very hard, indeed, to get it right to avoid the hollow force and to avoid, along with a hollow force, a hollow industry. One way to do this is by maintaining those features that gave us a special competitive edge -- the kind of edge that we saw in Desert Storm. To borrow a term from the business world, what we want to do is maintain an unfair competitive advantage over any military force that we might have to face in the future. Based on the history of Desert Storm, I would observe that there are at least three components to that competitive advantage. The first of those is our advantage in people, leadership. The second is the advantage of the readiness of our forces. And the third is our advantage in technology.

Today, I am going to focus most of my discussions about that third advantage, namely, the technological advantage. The first problem in maintaining that advantage is recognizing that most of the advantages in our deployed military forces and most of the technological advantages, come from our defense industry, that is, the technologies embodied in our defense industry. Therefore, one of the greatest challenges we'll have is to avoid this industry becoming hollowed out by the dramatic changes in the size of the market. I talked about a 40 percent reduction in the defense budget. That is a smaller decrement than industry has to confront. Because we have already had a 50 percent decrease in the procurement count and that decrease is likely to go to 60-65 percent by the mid-1990s. You are looking at almost a two-thirds decrease in the size of the market that is available to the defense industry. This is an enormous challenge for managers in the defense industry and an equal challenge for the managers in the Defense Department to try to preserve the vitality and the effectiveness of our industry at this much smaller level. I don't have any doubt that the smaller industry could be effective. The difficulty is in managing the transition, getting to that smaller size without crippling the industry on the way.

I want to suggest some things that can be done to meet this challenge and, primarily, to focus on how technology can be used to meet this challenge. The Defense Department, first of all, has to make some hard decisions about its R&D budget. We want to protect our technological advantage; we have to protect the technology base portion of our defense budget. I have committed to the President and to the Congress to do what I can to see that that happens. We have, for example, in the fiscal 94 budget an enormous cut in the procurement budget - 17 percent proposed. On the other hand, the R&D budget is maintained essentially flat. This is one manifestation of our attempt to maintain a robust research program in the face of this dramatic decline in the top line. Industry also has to make some hard decisions relative to its R&D program; in particular, they have to decide whether they can sustain their independent R&D program in the face of the decline of their business base. Industry's ability to provide low-cost, high-quality product and improved processes depends on maintaining a vigorous R&D program.

Let me give some examples of the ways I think technology is going to be very important to this process in the future. Instead of focusing on products that come out of the Defense Department, let me instead focus on manufacturing and design process. I believe that our future in defense is going to hinge on dramatic improvements in our design and manufacturing process, and that the key to that effort is through applications of advancements in information technology. It is a well-known cliche that we are on the verge of paperless manufacturing and paperless design, but we have to transform the rhetoric into reality. Many companies are trying to do this today. Many companies are forming integrated design manufacturing teams where they bring engineers and manufacturing together at the very beginning of a project and where the entire flow of ideas, designs and standards is embodied in the computer and not through blueprints and documents. This type of approach will greatly reduce production costs and development times, especially by dramatically reducing the need for rework, which costs both time and money. It also will make it much easier to do concurrent engineering, where the manufacturing staff participates by pointing out possible manufacturing designs or shortcuts early in the process -- not after it is too late.

If we now look from the companies back to the Defense Department, we see that our entire acquisition system is awash in paper, and the application of modern information technology is one of the major challenges we face to deal with our problem. We've been struggling to do that since 1985 through the computer-aided acquisition and logistics support program. In the next few years, we have to get out of the struggling phase and into the achievement phase on costs; that would be one of my primary objectives in overseeing the acquisition system.

The secondary I would like to point out to you of importance in the application of technology is applying it to commercial products, that is defense companies applying technology developed on defense programs to commercial products. Last week, I spent a day at the Hughes Aircraft Company, which has many programs underway that could be described as "defense conversion." They don't use that term by the way, they use the term "defense diversification." (I think that may be in response to the bad name the defense conversion got not only from the history of failures but, more recently, from Norm Augustine's paper on foreign affairs where he cripted that the "defense conversion is unblemished by success.") It may be unblemished by success, but our defense diversification efforts are already off and running and indicating very great prospects for success. Hughes, for example, has modified a heads-up display, which is developed for fighter aircraft, and is now using it for police cars in a very creative and innovative fashion. They are modifying some of their radar technology for use in school buses to protect the children as they get on and off the bus. They are working on electric cars. I had the pleasure of driving one of their electric cars and the image that you get from driving a golf cart is the wrong image. This little electric car they have has so much pick up that I almost got whiplash as I drove down the street in it; it's a very impressive automobile. And, indeed, they're working on application of some of the satellite technology to direct access home TV. These kinds of applications will be key in helping the defense industry to diversify.

In general, I believe, that the diversification in defense companies would be best done not through trying to develop consumer products, but rather by developing products which could be called infrastructure products: developments in the transportation systems, energy systems, telecommunications systems, food processing systems. The technology that is required, the management skills that are required, the marketing skills that are required are much more compatible with those skills embodied in the defense companies in trying to make a very large leap into consumer products.

We have the question in the Defense Department -- since we believe it is not only to the defense industry advantage, but to the Department's advantage to promote diversification -- what can we do in the Department to stimulate diversification? The first, and most obvious, is to allow the defense companies much greater freedom in their use of independent research and development money. I have directed that the supervision in the IR&D program that those funds should be used for the development of commercial products as well as the development of defense products. Basically, I am saying that diversification is an objective of the Defense Department and, therefore, diversification programs are suitable vehicles for the independent research and development effort. The second is we have put a very sharp focus on the DoD IR&D programs to dual-use efforts or trying to emphasize dual-use efforts. In the fiscal 94 budget, we will be approaching $2 billion worth of programs that are basically dual-use technologies. The companies that win these contracts will have, therefore, a technical base from which they can diversify. ARPA, of course, is playing a major role in these dual-use technologies, among other things through their so called Technology Reinvestment Program. This program is being managed by ARPA along with other Government agencies and the purpose is to explicitly promote and support diversification by providing 50 percent funding for those projects that have both an application to defense and a defined, specific application to commercial products.

A third action that we could take in the Defense Department to support diversification is to reform the defense acquisition system. That's going to involve making dramatic changes in the way we administer military-unique specifications, contract procedures and security procedures. In each of these three cases, we have instituted a unique way of doing business in the Defense Department, and these unique procedures have created barriers between defense components and commercial components of business even in the same company. Our objective will be to remove these barriers so companies can proceed on both commercial and defense business with more or less the same regulations and procedures governing them. This reduction of barriers will have two very great benefits. The first is that it will greatly facilitate companies ability to diversify, that is defense companies being able to develop and produce commercial products. It will also have a very direct benefit to the Defense Department in the sense that it will dramatically reduce the overhead costs that are associated with instituting and administrating these three barriers.

I don't have time today to go into details on this reform program, but I will sketch out a few specific near-term actions that are underway. The first of them has to do with specifications. We are in the process of changing from military-unique specifications to industrial-standard specifications by changing the preference rules. The preference today for the Program Manager is to use military specifications; if he wants to deviate from military specifications, he may do so by getting a waiver. Our proposal is to change that so that the preference would be to use industrial specifications. If a program wants to deviate to use military specifications, he could do that by getting a waiver. It seems to be putting the system on its head but I would point out to you that in many cases the use of MIL SPECS increases costs by 50 percent, 100 percent and, in some cases, in integrated circuits as much as a thousand percent and the principle is if you are going to invoke a more costly way of doing the job, you have to get a waiver to do it. There may be a compelling reason why you need to expend that extra cost, but the burden of the proof will be on the Program Manager.

Secondly, we propose to make substantial changes in the laws and regulations that cover defense contracting. The goal of these changes will be to make our acquisition system more like commercial acquisition. This is going to take some time to implement the laws that are specific to federal acquisition and to defense acquisition are a multitudeness You might say that the barnacles on a ship have been building up over the last 40 or 50 years and we are not going to shake them off overnight, but we are going to start scraping them off and we are going to start this summer. We are going to be building our proposals for acquisition reform on the so-called Panel 800 Findings, a study that was done under the leadership of the Defense Systems Management College over the last few years. The immediate and specific change we will be requesting is authority to use commercial acquisition approaches for all buys of commercial products -- seems like a straight forward and obvious thing to do, but we have not been doing it -- and authority to use commercial acquisition procedures on buys under a $100,000. Both of these sound like small potatoes compared with the major acquisitions we have underway in defense today, but that little change I am describing to you would dramatically simplify the process we and contractors use on more than 150,000 contracts. So the cost savings will be very very substantial by just those changes alone. And finally, we will be looking at changes that will apply to major acquisitions systems as well. I don't expect these changes to be made overnight. Instead, what we are proposing to do there is undertake, beginning this summer, four or five pilot programs. These will be large acquisitions systems. The purpose of the pilot program will be to demonstrate that substantial savings can be made if we waive certain laws. Pilot programs will go to the Congress and say for these programs we want the authority to waive the following specific laws. We believe that Congress will give us that authority on a pilot program basis and then we will be able to demonstrate through performance that (1) we really can make substantial cost savings, and (2) we can do it in such a way that protects the public trust.

I fully understand that acquisition form is going to be very difficult. Over the decades, there have been countless panels and commissions, boards, that have recommended ways to reform the defense acquisition system. My predecessors promised reform and all of them have failed, and that raises a very understandable question: "Why do I believe that we might be able to succeed today in the face of this history of failure?" I offer two reasons why the situation today may be different. First is the point I already made which is dramatic cuts in the defense budget. In a very perverse way, those cuts has opened up a window of opportunity for reform. That is, they have backed us into a corner where we have to make reform or we will be facing a catastrophic situation in not having enough money to buy even the most fundamental modernization components for our systems. The second point is that we have a team now that believes in reform and is committed to reform. We have leadership in the case of Secretary Aspin and President Clinton, who are not only permitting me to reform the system, they are demanding that I reform it. We have key members in Congress, in particular, the leadership in the House and Senate Arms Services Committee who are pushing for reform. All in all, we do have today the political environment not that *forces* reform, but that *permits* it to happen if we are bold enough and energetic enough to seize this opportunity. Within the Defense Department, the team that is forming under John Deutch, the Undersecretary for Acquisition, believes in this committed reform; Colken Preston is now the newly appointed Undersecretary of Acquisition Reform; Anita Jones, the new DDR&E; Gary Denman. This whole team is dedicated to and committed to improving this system.

Over a hundred years ago, Victor Hugo said "More powerful than a tread of mighty armies is an idea whose time has come." I believe that the idea of acquisition reform has come. This is its time, and we really intend to make it happen. I started off with a quote from Charles Dickens and I want to conclude with a quote from another English author, Lewis Carroll,. In *Alice in Wonderland*, there is a scene where Alice tells the queen "Oh there's no use trying. One can't believe impossible things." To which the queen replies, "I dare say you haven't had much practice. I've believed in as many as six impossible things before breakfast." I'm only asking you to believe two impossible things. First is the defense industry can diversify, and the second is that we can reform the defense acquisition system. With the help of the best acquisition professionals in the Defense Department and the support of the executives of defense industry, we may just be able to do those two impossible things.

Thank you very much."

MANUFACTURING TECHNOLOGIES SESSION IV

CHAIR: DR. MICHAEL F. MCGRATH

IV-A MATERIALS AND APPLIED SCIENCE

DR. BERT HUE AND DR. BENJAMIN WILCOX

ADVANCED RESEARCH PROJECTS AGENCY
3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

July 20, 1993

MEMORANDUM FOR DSO - WILCOX

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

Reference is made to the following material submitted for clearance for open publication:

ARPA MATERIALS SCIENCE RESEARCH

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G. T. Winn
Technical Information Officer

Attachments

CC: K Rajan

ARPA Materials Science Research

Ben A. Wilcox

Sixteenth ARPA Systems and Technology Symposium

22-24 June 1993

Naval War College
Newport, Rhode Island

MATERIALS SCIENCES / DSO

<u>Dr. Ben A. Wilcox</u>

Advanced Materials Synthesis and Processing Program

<u>Mr. William G. Barker</u>

Intelligent Processing and Manufacturing
- Diamond Substrates
- Carbon-Carbon Composites
- Metal Matrix Composites
- Multi-Chip Modules *
- Thin Film Photovoltaics

<u>Dr. William S. Coblenz</u>

Ceramic Insertion, Fibers, Composites, and Bearings

Solid Freeform Fabrication *

<u>Dr. C. Robert Crowe</u>

Polymer Composite Processing

Smart Materials and Structures *

<u>Mr. Jon B. DeVault</u>

Polymer Composite Manufacturing *

<u>Dr. Richard T. Loda</u>

Batteries and Fuel Cells *

Hazardous Material Demilitarization

Environmental Sciences

<u>Dr. Frank W. Patten</u>

High Temperature Superconductivity

Multi-Chip Modules *

Magnetic Thin Films

* FY94 New Starts

COMPOSITES

Objectives

- Selectively advance DoD mission capability via synthesizing, processing, and manufacturing of affordable composites (PMC, MMC, CMC, CCC).
- Tailor strength, stiffness, and other directional properties (electrical and thermal conductivity, coefficient of thermal expansion) for specific applications.

Emphasis

- Primarily aerospace, but new opportunities in naval warfare (submarines), land warfare, and thermal management in electronic packaging.
- Reduce cost by intelligent processing of materials and automated manufacturing of components and structures.

CONSORTIA/PARTNERSHIP RESULTS
(Materials Related)

Pre-Competitive Consortia

FY91

- Ceramic Fiber Consortium
- Composite (Organic) Automation Consortium
- Rapid Preforming Technology for PMC, CMC Composites
- Consortium for Superconducting Electronics

FY92

- Precision Investment Casting Consortium
- Micromagnetic Components Consortium
- Ultra Dense Capacitor Materials Processing Consortium

Advanced Materials & Processing Partnerships (AMPP)

FY92 (Four Partnerships Negotiated)

- MBE In-Situ Process Control Partnership
- Organic Thin-film Materials for Optoelectronics Technologies Team
- Affordable Polymeric Composites Team
- Smart Materials and Structures Team

FY93 (Five Partnerships Being Negotiated)

- 2 Composites (CMC; CMC & MMC)
- 2 Electronic/Photonic Materials

INTELLIGENT PROCESSING OF MATERIALS (IPM)

<u>Goal</u>: Improved quality and reduction in manufacturing costs.

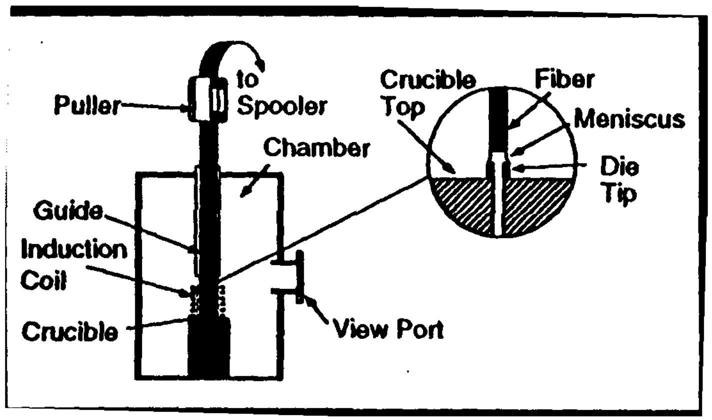
<u>Approach</u>: An integrated manufacturing methodology in three parts which reduces reliance on quality control of finished components to detect up stream manufacturing sources of variability.

1. Development of physical process models which relate the material properties of interest with the processing conditions. Utilization of experience-based models where physical-based models lack the detail to adequately relate control and behavior parameters.

2. Use of process sensors to measure processing conditions (i.e., temperature, pressure, shape/size, rate).

   and

3. Utilization of sensor data with appropriate control theory for the real time correction and control of the manufacturing process.



Puller
to
Spooler
Chamber
Guide
Induction
Coil
Crucible
View Port
Crucible
Top
Fiber
Meniscus
Die
Tip

SOLID FREEFORM MANUFACTURING

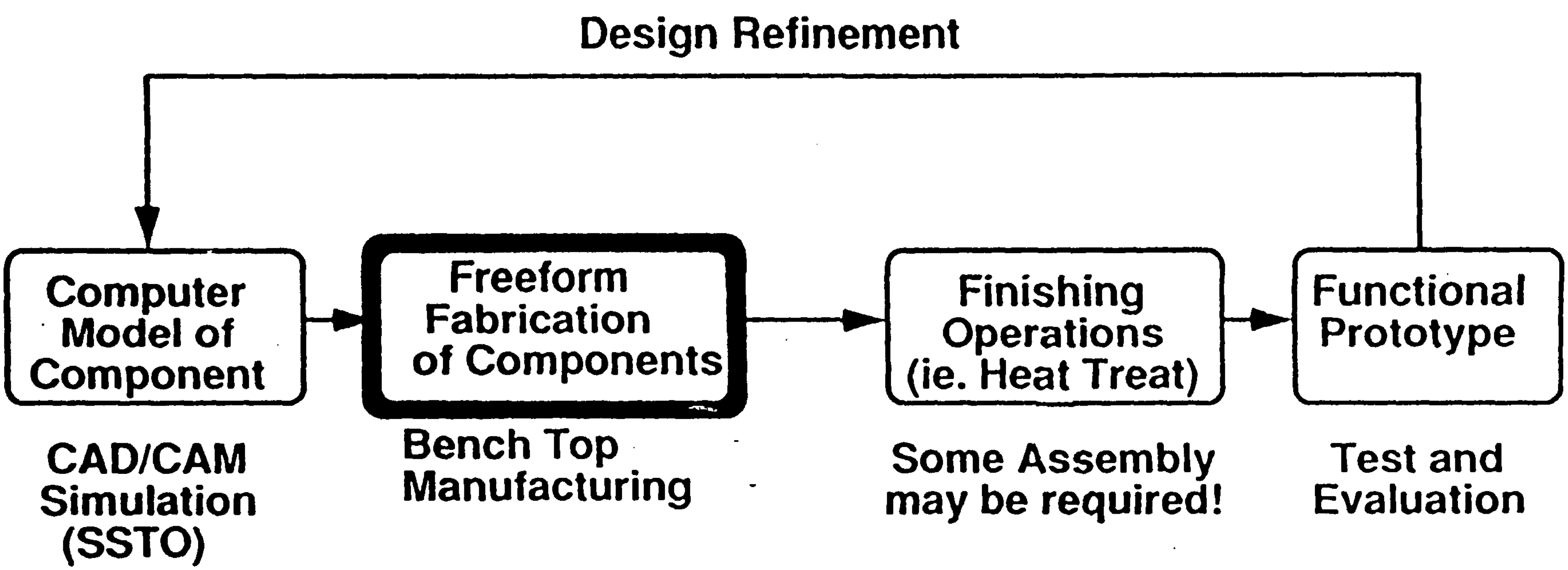
Technology

Solid Freeform Fabrication is the capability to convert virtual objects (i.e., CAD files) to solid objects directly without part specific tooling or operator intervention. Solid objects to be produced in plastic, metal, ceramic or a combination of materials. Technology includes the inverse operation (digitizing of solid objects).

DoD Imperative for Technology

- Rapid new product acquisition
- Flexible manufacturing for small volume production runs

FREEFORM MANUFACTURING



Material Choices: Ceramics, Metals, Polymers, and <u>Combinations of Materials</u>

Component Demonstrations: Mechanical Test Specimens, Ceramic Turbine Rotor, Metal Matrix Electronic Packaging,....

FREEFORM STATE-OF-THE-ART
(as contrasted with mass manufacturing)

- Ability to Digitize Solid Objects: Facilitates the conversion of solid objects to Virtual Objects: Need data file compatibility
- Solid Freeform Capability:

Plastic	available, most mature (photolithography)
Wax	demonstrated, investment casting
Metals	indirect capability
Ceramics	demonstrated for molds and cores (laser sintering)
Composites	metal matrix composites demonstrated from fabricated powder preforms

Functionally Gradient Materials: Variable composition capability, Not demonstrated as yet

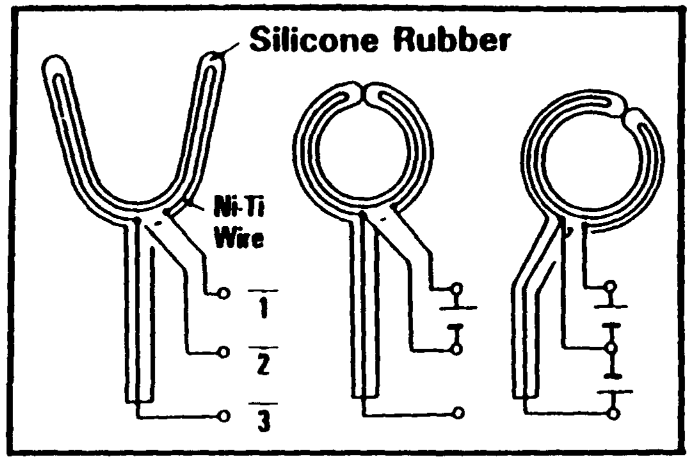
Machines: Assembly of discrete parts (ie. gear assemblies) has been demonstrated!

SMART MATERIALS, DEVICES, AND STRUCTURES

Concept

Develop materials, devices, and structures which have the capability to both sense and respond (e.g., change shape) to environmental stimuli

- ► **Active sensors – respond to artificial stimuli**
- ► **Passive sensors – respond to environment in which they operate**



Heat Activated Micro-Manipulator

Receptors/Effectors

- ► **Piezoelectric**
- ► **Magnetostrictive materials**
- ► **Electrostrictive materials**
- ► **Optical fibers**
- ► **Hybrid fibers**
- ► **Shape memory alloys**

Potential Applications

- ► **Control of optical surfaces**
- ► **Control of hydrodynamic surfaces**
  - **Torpedo quieting**
  - **Aircraft control surfaces**
- ► **Robotics**
  - **Tactile members**
- ► **Stealth**

ELECTROCHEMICAL POWER SOURCES

- Li-Polymer Battery
  - Current Program
  - Battery Technology BAA (FY94) BAA 93-XX
- Direct (Methanol) Oxidation Fuel Cell
- Fuel Cell Power Plant Initiative, BAA 93-18, FY93 Congressional Add
- Logistic Fuel Cell Program (FY94-FY98) BAA 93-XX
- Technology Reinvestment Program (Advanced Batteries and Vehicle Alternate Power Sources)

FY94 BATTERY TECHNOLOGY BAA

- BROAD AGENCY ANNOUNCEMENT (ARPA BAA#93-XX): BATTERY TECHNOLOGY FOR: A) FLEXIBLE MANUFACTURING, RAPID PROTOTYPING OF SOLID POLYMER ELECTROLYTE, RECHARGEABLE AMBIENT TEMPERATURE BATTERIES; AND B) EXPLORATORY R&D ON RECHARGEABLE BATTERIES. ARPA BAA#93-XX POC in ARPA/DSO, Dr. Richard T. Loda, (703) 696-2283.

- Focus - a) Fully automated, flexible maufacturing and rapid prototyping of Li-Polymer.

  b) Novel Concepts - "green", organic, instant rechargeable such as RT direct MeOH FC, BOC, Zn-air, Ni/Zn, NiMH, etc...

  c) Portable electronics vs EV.

LOGISTIC FUEL CELL POWER PLANT

- ARPA BAA 93-18, $11.8M FY93 (2-years)

Specific issues to be addressed in this program include:

(1) analytical optimization and experimental verification of a fuel preprocessor for operation of a FC on DF-2 or JP-8,

(2) development of a FC stack design that specifically addresses any unique militarization and transportation issues and demonstration of the design at the >30KW level,

(3) design and development of a brassboard fuel feed system and testing it with a >30KW FC cell stack,

(4) preliminary design of a two megawatt-class logistic fuel cell FC for a fixed base application, and

(5) preliminary design of a similar unit of the maximum rating to be transportable as part of a bare base deployment.

LOGISTIC FUEL CELL PROGRAM

OBJECTIVE: To develop and demonstrate the technology required to utilize DoD "all-purpose" logistic fuels in a fuel cell power plant to meet a wide range of future DoD requirements.

- Demonstrate prototype fuel processing subsystem capable of generating fuel cell quality gas feed from from military logistics fuels, e.g. JP-8 or DF2. (3 year intermediate goal)
- Incorporate fuel processing subsystem and an existing fuel cell stack from an on-going program (such as the 15kW UUV program) in a complete prototype mobile fuel cell power system of >500W.
- Build on present ARPA fuel cell program to initiate R&D of a novel direct oxidation approach to a man-portable power unit, and demonstrate a <500W fuel cell operating on "all-purpose" logistics fuel.
- PAYOFF: "Silent Power" (>28db), >100x reduction in emissions, improved reliability, lower maintenance, higher efficiency, modular and scalable. Inter-operability, uses DoD all-purpose fuel for Mobile Electric Power (MEP). First "multi-kW" FC power plant with logistics fuel capability for DoD application.
- FY94-98

CERAMIC FIBER PRECOMPETITIVE CONSORTIA

OBJECTIVES

- Develop ceramic fibers for reinforcing ceramic Matrix (and possibly metal matrix) composites
- Ceramic matrix composite use temperature 2500 to 3000 ^{o}F
- Ready for commercial scale-up in 3 to 5 years

APPROACH

- Seven major U.S. gas turbine engine companies form a not-for-profit consortium
- Research funding will be from consortium partners ARPA, Air Force, and NASA
- Consortium will fund developers of ceramic fibers

CHARACTERISTICS OF CFC

- Not-for-profit
- Board of directors from engine companies (ex officio representatives from government)
- CFC awards contracts to U.S. Industries and Universities from competitively selected proposals
- Participation of government program managers in contract selection/project management

MEMBERS

- Allied-Signal Aerospace Company-Garrett Engine
- Teledyne CAE
- Williams International
- Allison Gas Turbine - General Motors Corporation
- Textron Lycoming
- General Electric Aircraft Engines
- Pratt & Whitney

ADVANCED RESEARCH PROJECTS AGENCY
3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

August 2, 1993

MEMORANDUM FOR DSO - HUI

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

Reference is made to the following material submitted for clearance for open publication:

APPLIED SCIENCES

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G. T. Winn
Technical Information Officer

Attachments

cc: K Pulgrom

2 The Applied Sciences Division will initiate a number of new programs in FY 94: (1) optical fiber communication technology, (2) modeling, simulation & control, (3) holographic data storage, (4) flexible laser tooling, and (4) advanced bio-medical technology. We will describe briefly a few of these programs.

3 The objective of the optical fiber communication technology is to dramatically improve the performance of the network by moving away from mostly electronic components to almost all-optical devices. So instead of converting the carrier from photonic to electronic format to perform the switching and regeneration, the goal to is avoid the electronic bottleneck and transmit information by photons end-to-end.

4 The bandwidth capacity at 1.3 and 1.55 micron is almost 30 THz. One way to increase the bandwidth capacity is to transmit information in parallel channels. By using wavelength-division-multiplexing, one may dramatically increase the network performance. A totally new class of devices, architecture and protocol will have to be developed to implement this multiplexing scheme. Another new format of transmission is to use very short pulses, tens of picosecond, to carry the information. An example is soliton which is a kind of nonlinear propagation with dispersion exactly cancells out nonlinearities. These two schemes together with others will be investigated in this program.

5 The applied and computational mathematics program develops basic techniques in simulation and modelling for a wide range of applications. Examples are wavelets for data compression and signal processing, and fast multipole method for solving electromagnetic scattering problems in complex structures. In FY 94, a new program in simulation and modelling will be initiated with emphasis in lithographic process and advanced material processing. The goal is to develop advanced computational algorithms to simulate the manufacturing process and to cut down the number of prototype cycles and therefore reducing cost.

7 The compact lasers has different components but it essentially supports both military and commercial applications. The ongoing programs support infra-red countermeasure and laser radar. A new program in FY 94 will emphasize the application of diode-pumped solid state lasers for manufacturing. The combination of wavelength diversity, size and weight, high beam quality will enable a totally new class of machine for cutting/drilling, welding and surface treatment of materials.

DEFENSE SCIENCES OFFICE

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(Director)

Mr. Jon DeVault
(Senior Scientist)

Material Science

Dr. Benamin Wilcox
(Dep. Dir)

Mr. William Barker

Dr. William Coblenz

Dr. Richard Loda

Dr. Francis Patten

Dr. Robert Crowe

Applied Sciences

Dr. Bertram Hui
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Dr. James Crowley
(Lt. Col, USAF)

Dr. L. N. Durvasula

Dr. Ira Skurnick

Applied Sciences / DSO

ARPA

DSO

<u>Dr. Bertram Hui</u>

Optical Fiber Comm. Tech*

RF Technology:

— Vacuum Electronics

— EW / Advanced Radar

<u>Dr. James Crowley (Lt. Col, USAF)</u>

Applied & Computational Math.

— Modeling, Simulation & Control *

— Signal Processing / Wavelet

— Scalable Libraries

<u>Dr. L. N. Durvasula</u>

Compact Lasers

— EOCM, IRCM, Laser Radar

— Flexible Laser Tooling *

Holographic Data Storage *

<u>Dr. Ira Skurnick</u>

Advanced Bio-Medical Technology *

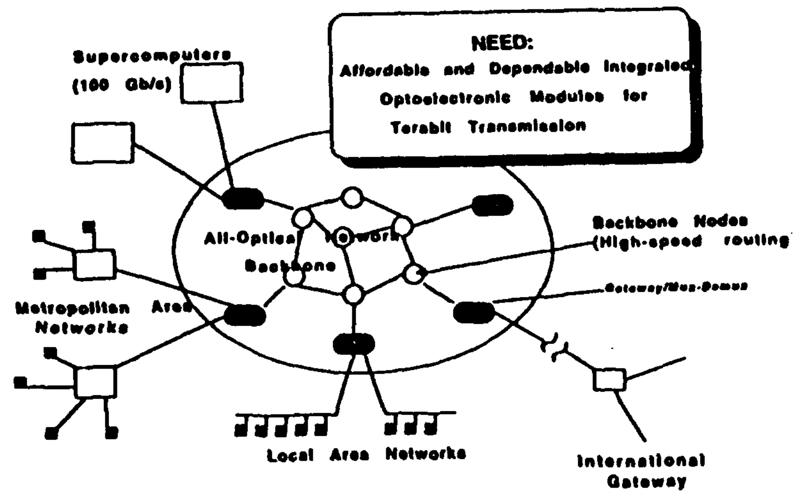
* FY 94 New Starts

GLOBAL GRID TECHNOLOGIES

DSO

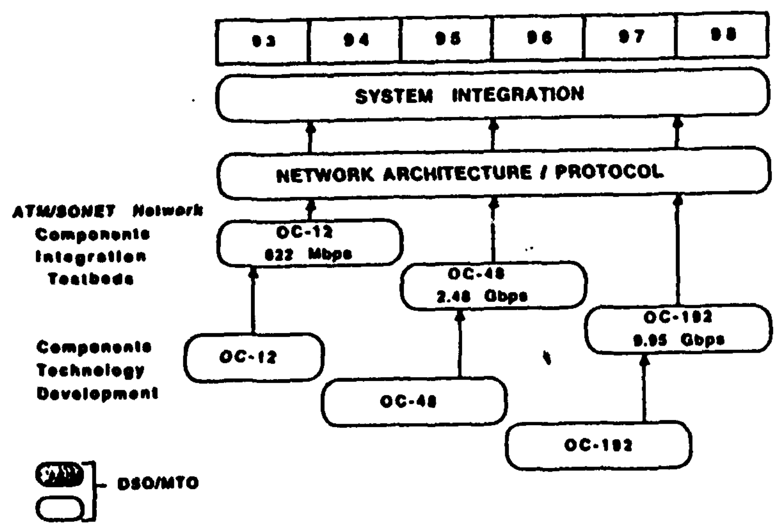
5 - Year Program Goals

1. Develop key components to enable OC-192 (9.95 Gb/s) ATM/SONET networks.
2. Develop components to support future generations of ultra-fast all-optical networks (e.g. soliton).

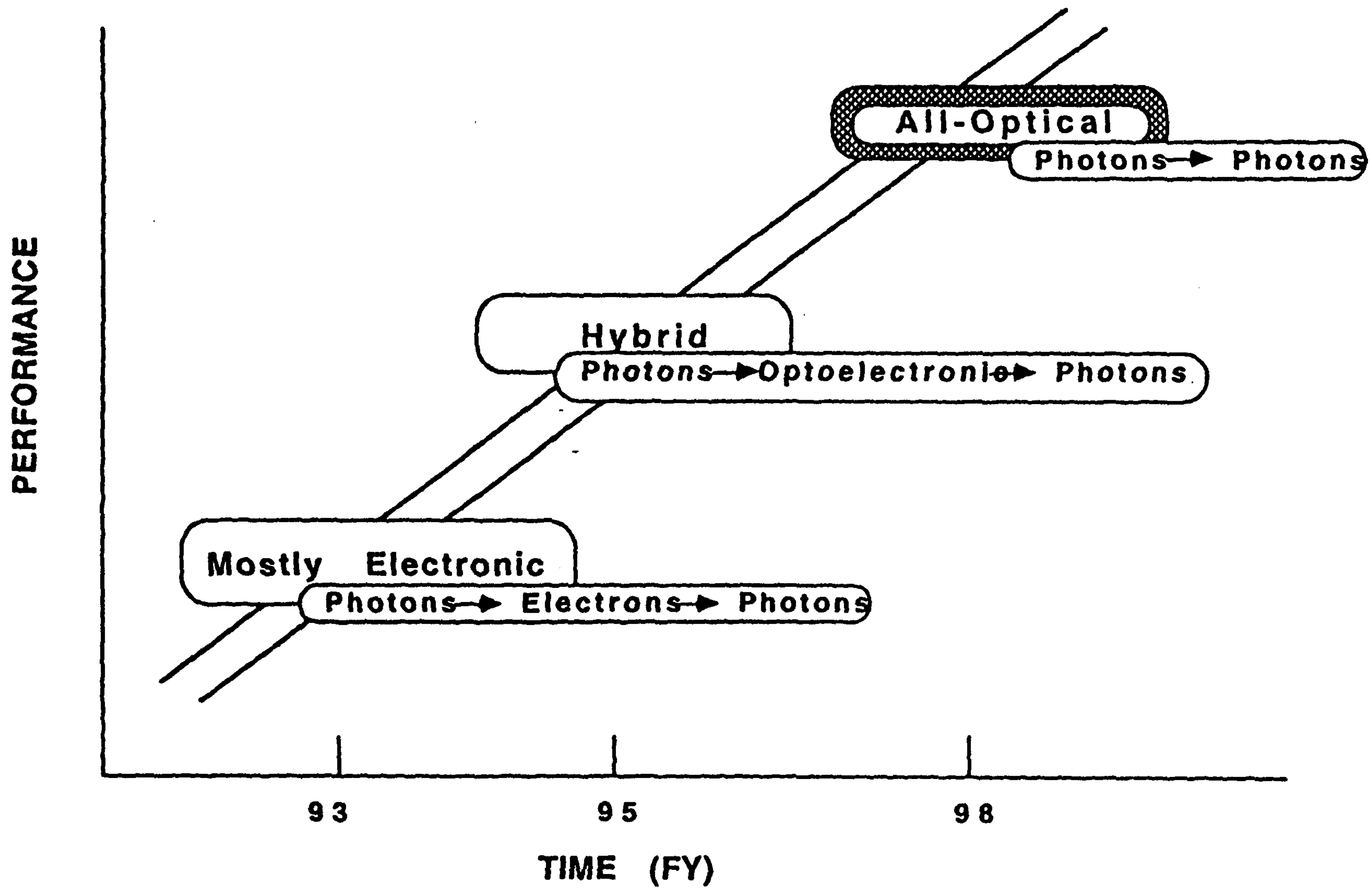


Technologies

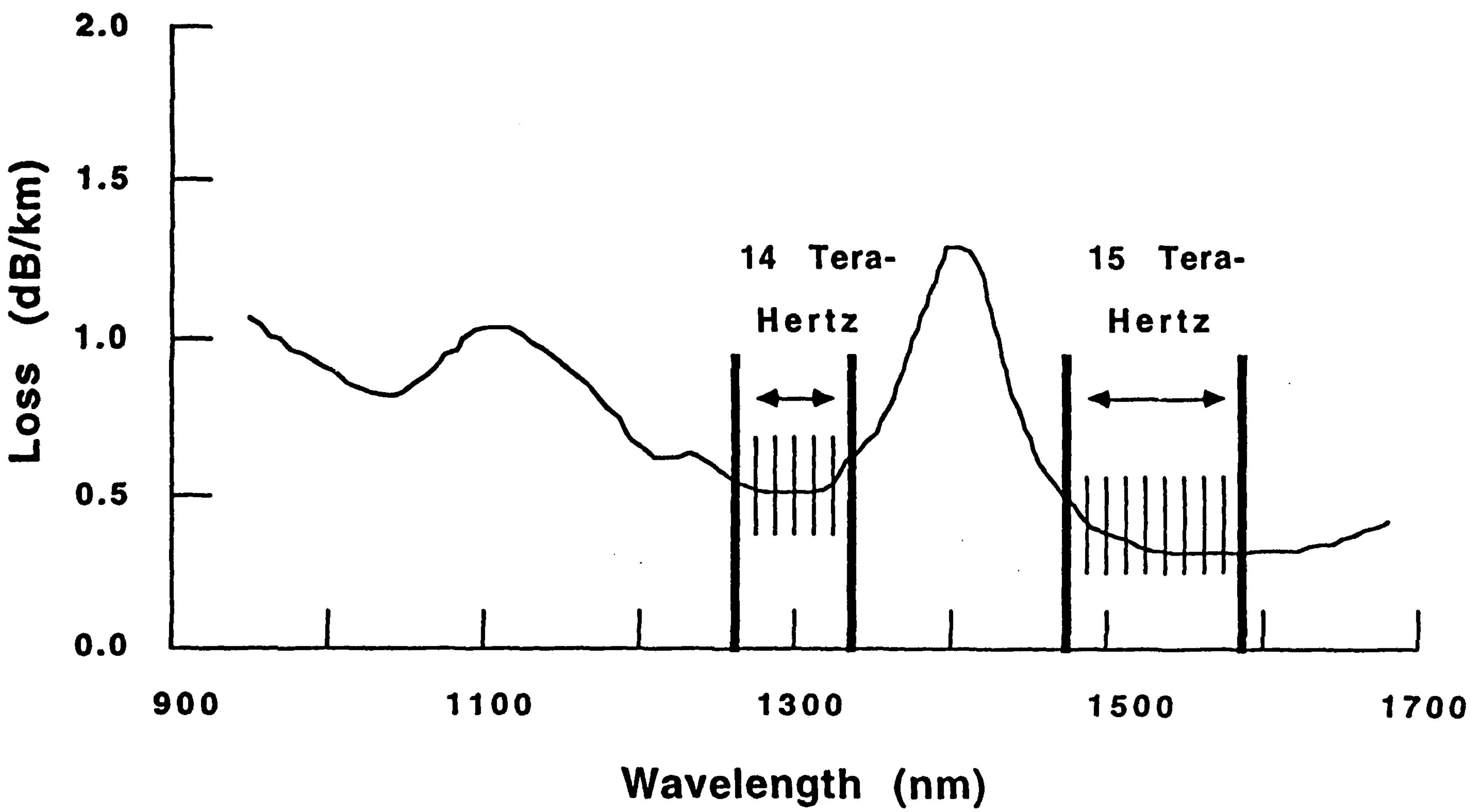
Transceivers	Wavelength Translators
Amplifiers	Filters
Routers	Synchronizers
ATM Switch	Mux/Demux



NETWORK COMPONENTS PERFORMANCE VS TIME



Bandwidth Capacity of Single-Mode Fiber



APPLIED AND COMPUTATIONAL MATHEMATICS PROGRAM

ARPA

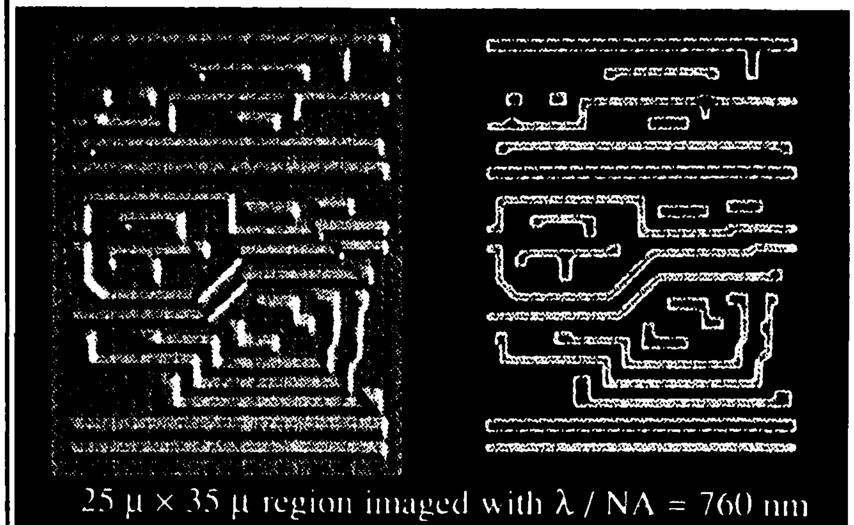
Themes:

- Leverage Advances in HPC
- Develop Algorithms & Computational Methods for High Payoff Applications
- Exploit Recent Advances in Applied Mathematics which have Strong Potential for Applications; e.g.,
  - -- Wavelets/Multiresolution Methods
  - -- Fast Algorithms (e.g. Fast Multipole)
  - -- Control of Complex Systems
- Rapidly Demonstrate and Transition Results to Applications

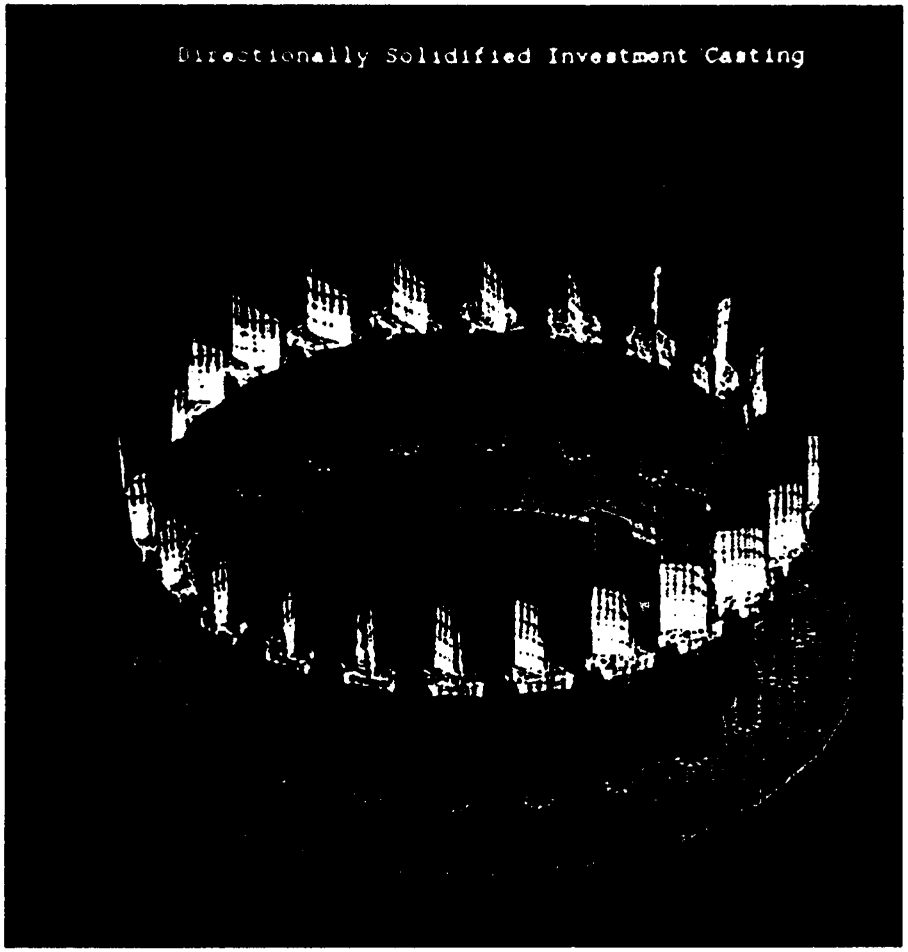
Payoffs: Methods & Codes Targeted at Specific Critical Applications

Applications:

- Computational Electromagnetics
- Materials Processing; e.g.:
  - -- Simulation of Investment Casting
  - -- Lithographic Process Modeling
- Signal/Image Processing
  - -- Automatic Target Recognition
  - -- Communications/LPI



MODELING, SIMULATION, AND CONTROL FOR ADVANCED MATERIALS PROCESSING



Goals:

- Develop computational simulation methods and codes to dramatically reduce cost and time to design while producing greater precision/uniformity
- Develop novel methods for in-situ sensing and real-time control of critical unit processes
- Demonstrate simulation/control on key processes
  -- Microelectronics fabrication
  -- Structural materials/coatings
- Foster collaboration between modeling/simulation/control and materials processing industry

Compact Lasers

Technology Development

Compact Lasers:

- Diode pumped solid state lasers with wavelength diversity in UV, visible and mid infrared spectral regions
- Tens of watts to kilowatt average power
- Laser and nonlinear crystals
- Diode laser arrays
- Phase conjugation and adaptive pointing/tracking

Technology Deployment

DoD Applications:

- EO and IR Countermeasures
- Laser Radar Applications

Flexible Tools in Manufacturing:

- Cutting/drilling, welding and surface treatment of metals and composites
- Automotive, airframe, aeroengine, ship building and heavy industry applications

Bio-medical Applications:

- Fiber optic delivery of laser energy for therapeutic and diagnostic applications
- Optical imaging

IV-B MICROELECTRONICS

MR. SVEN A. ROOSILD

ARPA

MICROELECTRONICS TECHNOLOGY OFFICE

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93-5-1940

930512.03

ADVANCED RESEARCH PROJECTS AGENCY
3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

June 21, 1993

MEMORANDUM FOR MTO - ROOSILD

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

Reference is made to the following material submitted for clearance for open publication:

MICROELECTRONICS TECHNOLOGY OFFICE

xxxxx The above referenced material was **CLEARED** for open publication by OASD(PA) on June 16, 1993, Case No. 93-S-1940. All copies should carry the following Distribution Statement "A" as follows:

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G. T. Winn
Technical Information Officer

Attachments

Microelectronics Technology Office

Sven Roosild, Acting Director

ARPA/MTO
3701 N. Fairfax Drive
Arlington, Va 22203-1714

It is my pleasure to be here today to give you an overview of the activities of APRA's Microelectronics Technology Office (MTO). My overview presentation will be followed by two more detailed talks that address relatively new programs in MTO: the ULTRA program (ultra-dense, ultra fast computing components) and Flexible IRFPA Manufacturing.

Fig. 1

MTO programs fall into three broad categories: Microelectronics Beyond Silicon -- investigations into semiconductor technologies that overcome the performance limitations of conventional silicon based technologies; Microelectronics Manufacturing -- efforts that primarily focus on today's limitations in semiconductor components manufacturing; and Infrared Focal Plane Arrays -- programs that first and foremost address the high cost of today's HgCdTe based infrared imagers and secondarily investigate new infrared imaging technologies such as multispectral sensors and sensors based on quantum wells.

Fig. 2

The ULTRA program has both a microelectronics and an optoelectronics component. Thus it is a program for which responsibility is shared by two program managers in MTO. Since a detailed presentation on this program will follow, be it sufficient that you note the major components of this program at this time.

Fig. 3

MTO has had a vigorous program in Optoelectronics for a number of years. In its course MTO has demonstrated how optoelectronics can surmount barriers to computing speed imposed by conventional electronics. Optoelectronics is working its way into the computing world by overcoming bandwidth limitations in the input/output circuits at each stage of signal transmission; i.e. initially between computers, then between boards and eventually chip to chip.

Fig. 4

This illustration shows the reduction in back-plain wiring complexity as copper wires get replaced by optoelectronic interconnects.

Fig. 5

Along with the research and development program in optoelectronics, MTO has actively pursued the transition of promising optical components into military systems.

Fig. 6

In the program know by the acronym TOPS ten candidate insertion programs are currently underway.

Fig. 7

Another major effort in MTO involves the theory, applications and hardware development associated with artificial neural networks (ANN) technology.

Fig. 8

In recent tests it was demonstrated that ANNs can outperform currently employed automatic target recognition systems such as template matchers.

Fig. 9

A vital link between real world signals and electronic signal processing is the analog to digital converter (ADC). The recent emergence of heterojunction bipolar transistor (HBT) technology has opened up the opportunity to push the envelope of ADC functions to wider bandwidth and higher dynamic range. In order to utilize this opportunity MTO initiated a manufacturing technology program for HBTs where ADCs are utilized as proof of concept vehicles in demonstrating yield and performance repeatability on a well controlled fabrication line.

Fig. 10

The range of ADC operational parameters for various military systems areas is compared to the MTO ADC program goals.

Fig. 11

Having concluded the MTO programs in microelectronics beyond silicon, I now turn to our programs on microelectronics manufacturing. The cornerstone of this area is the promotion of the concept of flexible, intelligent manufacturing. Rather than rely on rigidly fixed manufacturing lines as practiced today, this concept relies full utilization of computer integrated manufacturing (CIM) in the manufacturing process, and an underlying structure of sophisticated modeling and simulation.

Fig. 12

If one looks at the history of the cost growth in state-of-the-art silicon wafer fabrication facilities, it is easy to see that a change has to occur. At $1.5B per facility, very few companies will be able to make the necessary investment and very few components will have the sales volume that can justify such an expense.

Fig. 13

By the year 2000 the challenge will be even greater.

Fig. 14

Thus a new approach to microelectronics manufacturing, based on low-cost cluster tools, real-time process modelling and fully integrated CIM, is the goal of MTO's intelligent, flexible manufacturing program.

Fig. 15

There are three elements to this approach...

Fig. 16

... that are further broken down for process modeling and optimization,...

Fig. 17

... for in-situ sensing,...

Fig. 18

... and for application of advanced control theory.

Fig. 19

A specific example of how such an approach works is given for a metal organic chemical vapor deposition system (MO-CVD) is depicted in the diagram.

Fig. 20

The proof-of-concept verification for the flexible, intelligent manufacturing methodology has been demonstrated by the MTO program on Microelectronics Manufacturing Science and Technology (MMST).

Fig. 21

In the MMST development, single wafer processing modules are assembled in a relatively dirty environment, certainly not class 1 or better, and yet state-of-the-art lithography and other processes have been demonstrated for most of the steps required to fabricate an integrated circuit (IC) chip.

Fig. 22

Another key program in MTO's manufacturing efforts is SEMATECH, a consortium of the key U.S. semiconductor IC manufacturers partnered on a 50-50 basis with the U.S. Government. It has become the key entity for transferring new manufacturing equipment and technology into U.S. companies.

Fig. 23

SEMATECH's first significant success was to turn around the decreasing share of the worldwide semiconductor equipment sales of U.S. companies.

Fig. 24

Next SEMATECH contributed to the turnaround in the worldwide market share for U.S. manufactured semiconductor chips.

Fig. 25

In the next phase of SEMATECH, the consortium will play a major role is implementing the goals of MTO's flexible, intelligent manufacturing plan.

Fig. 26

The final effort to enhance semiconductor manufacturability is focused on advanced lithography. This area is the cornerstone of modern ICs. MTO is focusing on .18μ and below technologies since equipment development in this area has to start more than two lithography generations ahead; i.e. SEMATECH just demonstrated .35μ technology; the equipment for .25μ technology has been under development for a number of years already and now is the last opportunity to effect the lithography tools to be used for the .18μ technology.

Fig. 27

Candidate advanced lithography tools for the various lithography minimum line width generation of technology and the year that process development and production are expected to start along with the density of transistors per chip is shown. As can be seen optical lithography will have to be replaced by some other higher resolution technology before the beginning of the year 2000 in process development.

Fig. 28

All advanced lithographys can be seen to have their strength and weaknesses. The choice for .18μ and below lithography is by no mean clear. For this reason MTO redirected its program in x-ray lithography to advanced lithography in FY93; thus adding programs in projection ion beam and projection electron beam lithography to its program.

Fig. 29

The infrared focal plane arrays program concludes the program overview of MTO. The primary goal of this program is to reduce the cost of HgCdTe based IR imagers. It has supported tri-service programs in missile seekers, target acquisition sights and infrared search and track (IRST) systems by providing a source of both staring and scanning arrays.

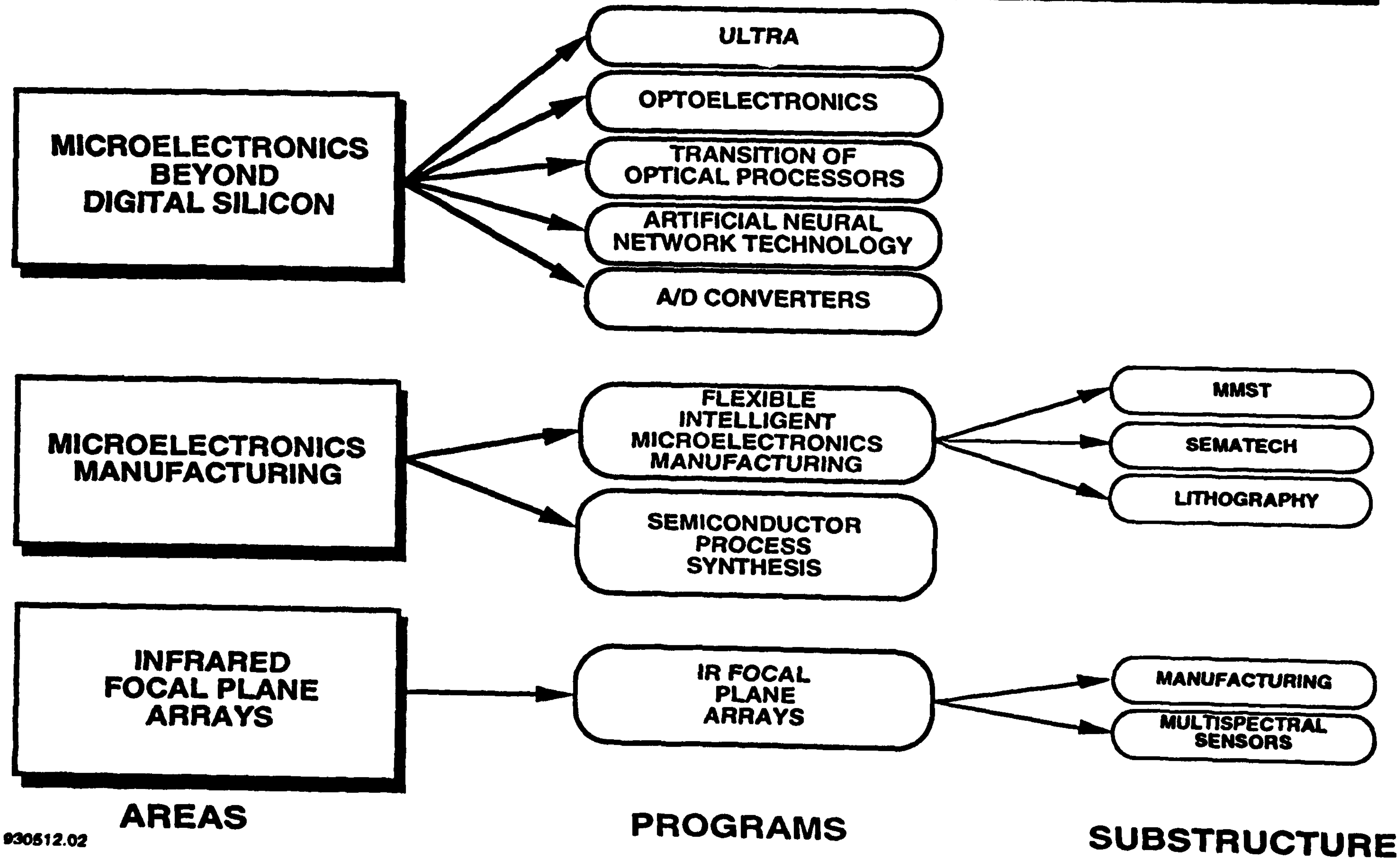
Fig. 30

A new effort, on which a full presentation will follow, is the application of MMST technology in the form of advanced vacuum processor (AVP) modules to the processing of HgCdTe. Here the flexible manufacturing concepts should have even a greater impact on reducing costs than they have in silicon IC fabrication.

Fig. 31

MTO has its program structured to implement the ARPA mission to "pursue imaginative and innovative research and development projects" as stated by Dr. Denman, Director ARPA in his Statement to Subcommittee on Defence, House Appropriations Committee on May 4, 1993. We are doing this by creating dramatic advances in technology and stimulating fundamental change in industrial capacity in critical aspects of microelectronics technology. This is done in all three main program areas: microelectronics beyond silicon, microelectronics manufacturing and IR focal plane arrays.

MTO PROGRAMS



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ARPA MTO

ULTRA

Develop ultra-dense, ultra-fast computing components

- Nanoelectronics
- Terabit memories
- Optical interconnect and I/O
- Optical computing
- Nanofabrication technology

FY 1992 - 97

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Andrew Yang
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OPTOELECTRONICS

Develop optical techniques to surmount conventional electronic computing barriers

- Optical interconnects to increase throughput
- Optical devices and materials

Cooperative university centers in optoelectronics

Precompetitive technology consortia - optoelectronic interconnects and all-optical networks

FY 1989 - 97

Program Manager: Andrew Yang
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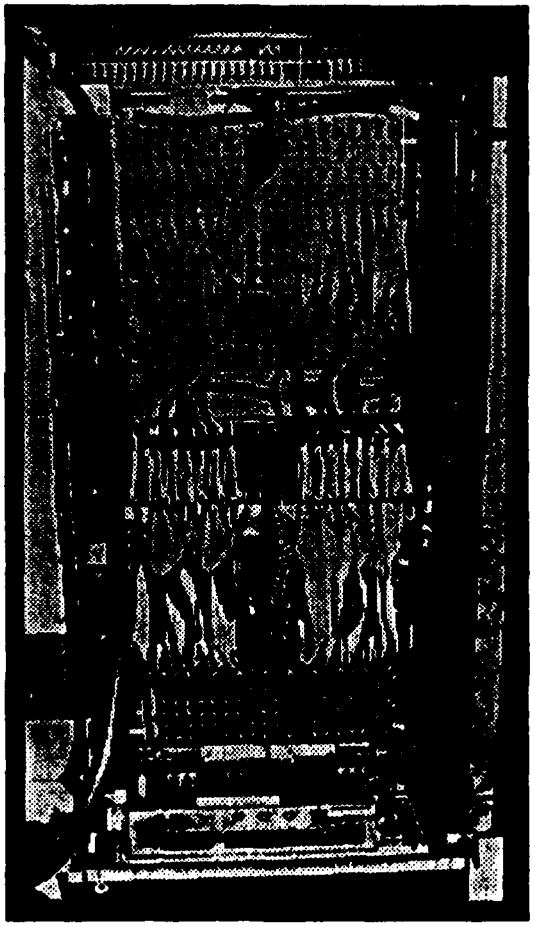
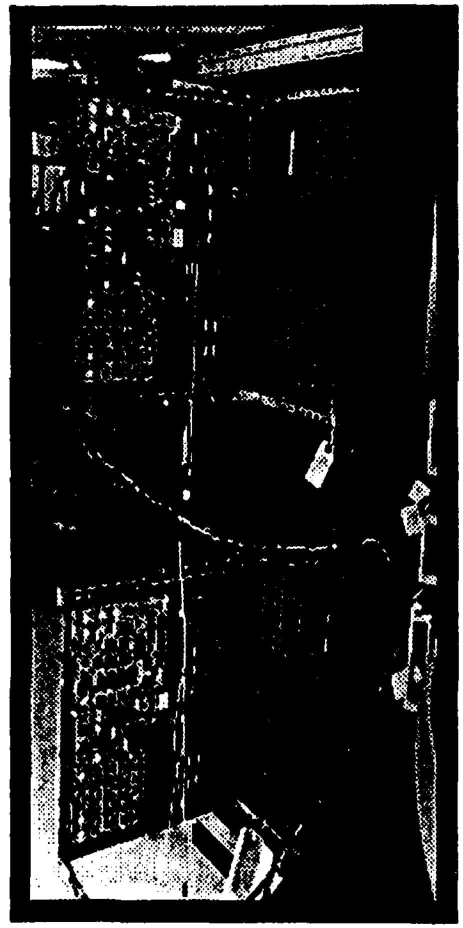
OPTOELECTRONICS INTERCONNECT REDUCES WIRING COMPLEXITY BY 500x





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TRANSITION OF OPTICAL PROCESSORS INTO SYSTEMS

ARPA MTO

Insert optical processing technology into existing, computation-intensive military systems

Demonstrate technology insertions
- 2 GHz channelizer
- Target recognition module
- Real-time, compact SAR with spotlight mode
- Optically controlled phased array radar beam

Field test demonstrated components

FY 1991 - 94

Program Manager: Andrew Yang
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ARPA

TRANSITION OF OPTICAL PROCESSORS INTO SYSTEMS

MTO

COMPANY	SUBSYSTEM	SYSTEM	PAYOFF
Harris	Channelizer	AN/SLQ-32 Shipborne Jammer	Size, weight, power reduction; simultaneous signals
Harris	Associative Memory	RC-135; Gnd. Proc. Sys.	Real-time ELINT airborne processing; ground processing time reduced by 95%
Martin Marietta	Pattern Recognition	Hellfire, NLOS	Improved hit probability
Teledyne Brown	Pattern Recognition	LRCSOW, NLOS	Improved accuracy and hit probability
Texas Instruments	Phased Array Control	AWACS	Ultimately leads to elimination of rotating antenna
Hughes	Phased Array Control	AST/AT	Meet size, weight restrictions
ERIM/BDM	SAR	GBU-15, B1B	Real-time processing; autonomous operations
Dynetics	Pulse Compressor	MRSR	Wideband capability
GE	Null Steering	AWACS	Greatly improved anti-jam capability
Harris	Direction Finder	AIEW	Faster response for jammer; multiple simultaneous threats

ARTIFICIAL NEURAL NETWORK TECHNOLOGY

Exploit immediate benefits of ANNs

- FLIR ATR
- Sonar ID
- Intelligent manufacturing
- Word spotting

Develop high-performance hardware systems

- Real-time computing on space-limited platforms
- Compute power for large-scale, complex problems

Develop theoretical base to apply sophisticated ANNs to currently intractable problems

FY 1989 - 96

Program Manager: Barbara Yoon
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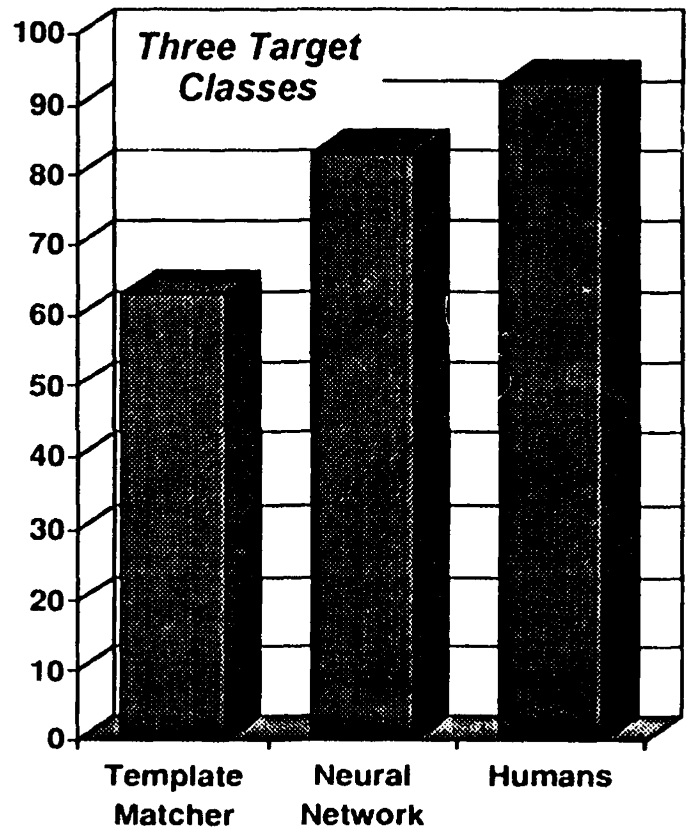
ARPA

MTO

AUTOMATIC TARGET RECOGNITION
COMPARISON: NEURAL NETWORK vs CONVENTIONAL

Typical FLIR Image



- 2x Reduction in Errors
- 1-Year vs 10-Year Development Time

ARPA CURRENTLY FUNDING AN INSERTION INTO COMANCHE

A/D CONVERTER DEMONSTRATION

Develop manufacturing capability for high-sampling-rate, high-accuracy interface electronics based on heterojunction bipolar transistor (HBT) technology

-A/Ds
-Multiplexers
-D/As

8-bit accuracy at 3-6 GHz
14-bit accuracy at 100 MHz

Develop high-speed circuit design tools

FY 1992 - 97

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930324.19 revised 5/12/93

HBT/ADC MILITARY APPLICATIONS/NEEDS

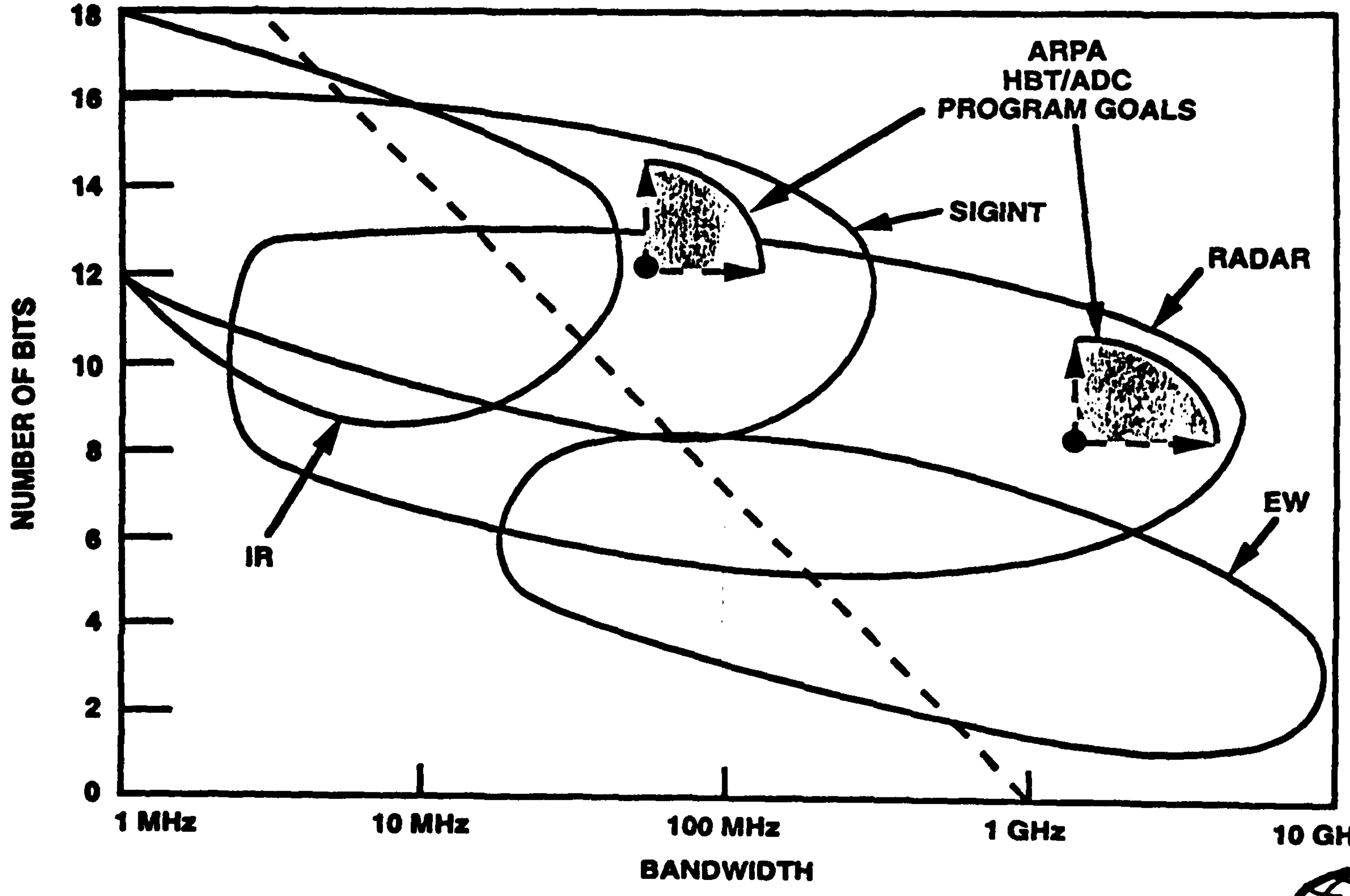
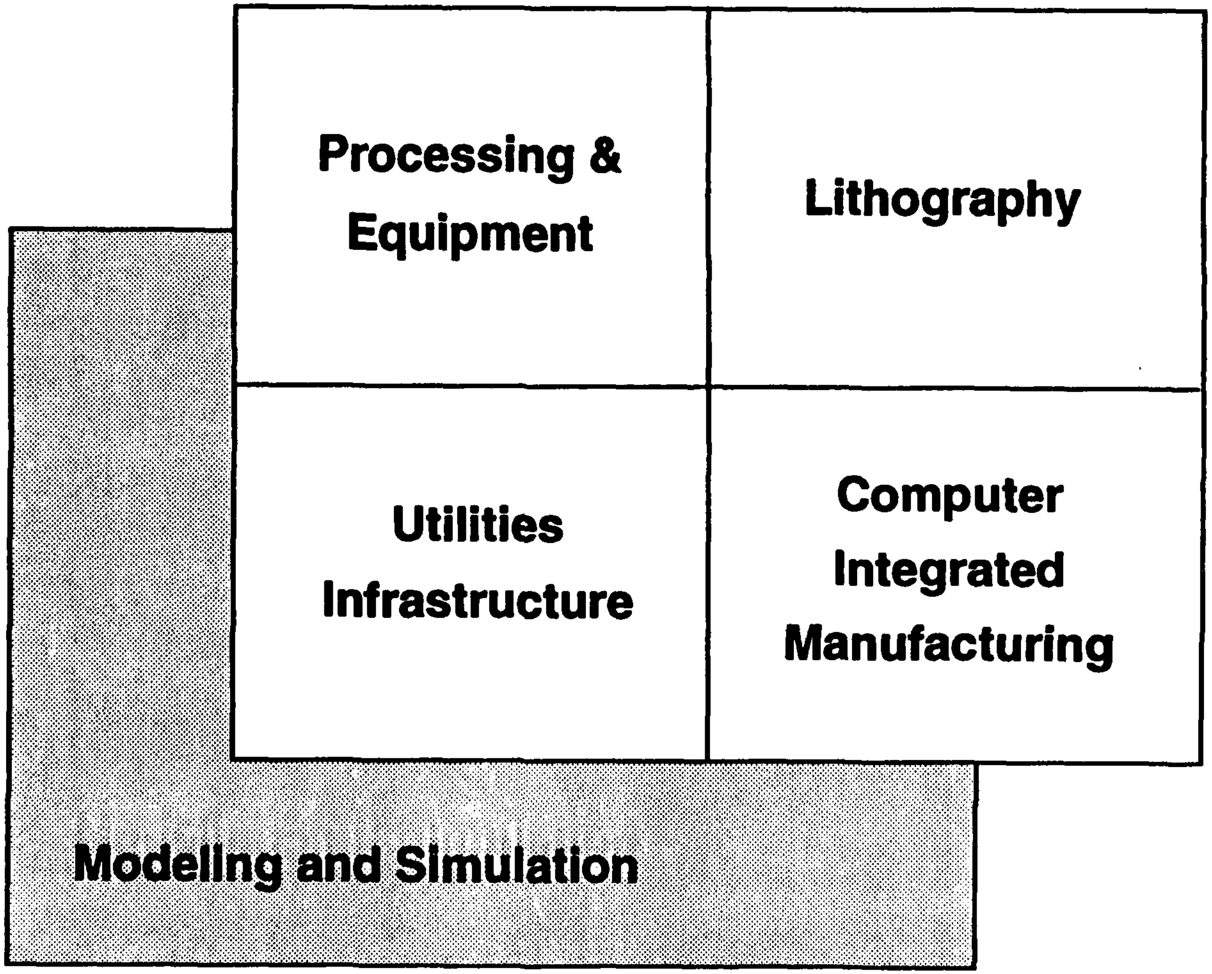


FIG #10

FLEXIBLE INTELLIGENT MICROELECTRONICS MANUFACTURING

Key Elements



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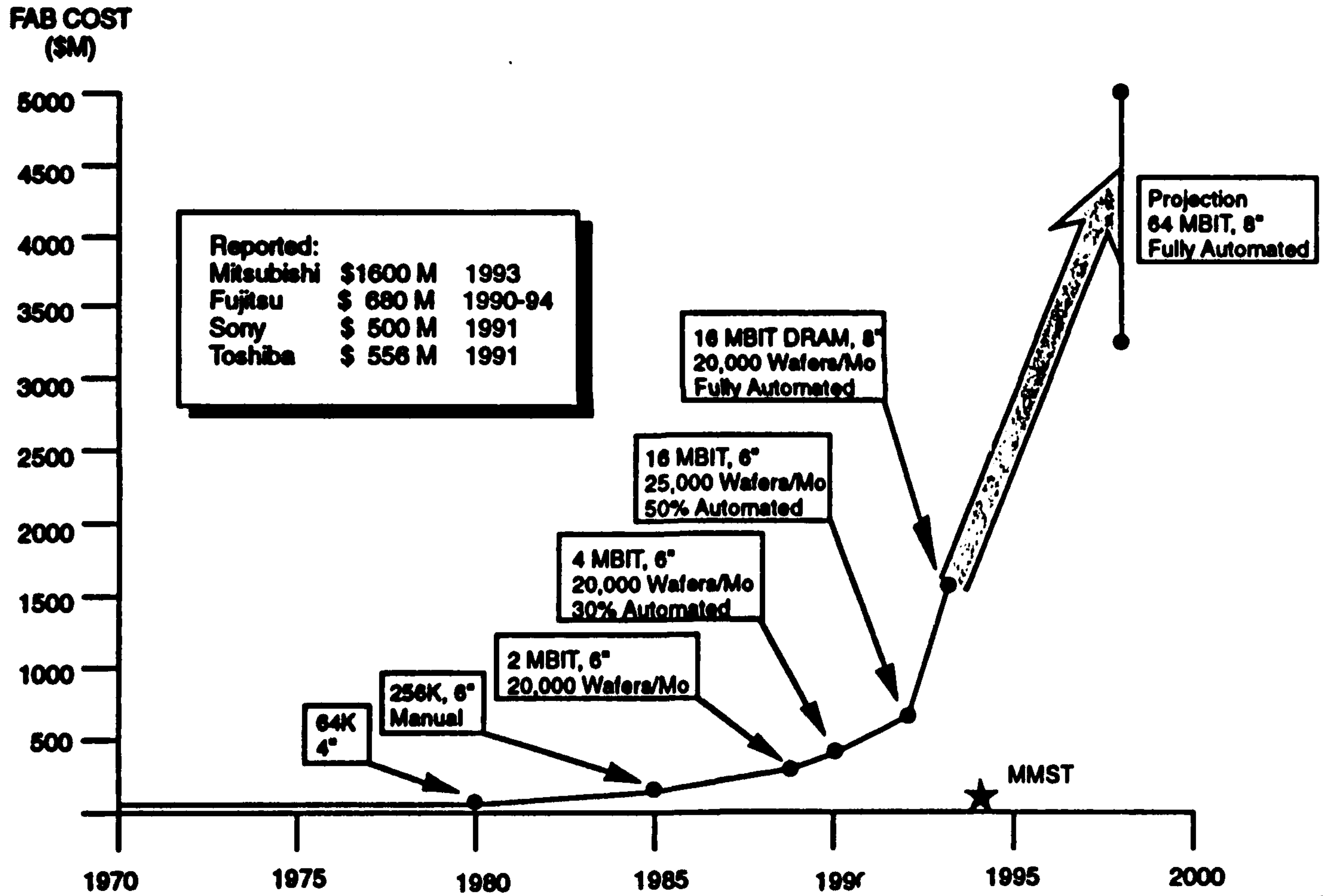
WAFER FABRICATION COSTS



THE CHALLENGE

The microelectronics manufacturing challenge for 2000 is to make ...

- 10^8 interconnected transistors/cm^2
- With 10^{-5} cm features
- Across 700 cm^2
- For ~10^1 dollars/cm^2

ARPA

A NEW APPROACH TO MICROELECTRONICS MANUFACTURING

MTO

TODAY'S STATE OF THE ART FAB	GOAL: LOW-COST, FLEXIBLE FAB
100s of large, different pieces of equipment costing $200K-$3M each	10s of cluster tools with standard mechanical and communications interfaces; modules & handlers cost $250K each
65,000 ft^2 of class 1-100 clean space	Microenvironments in class 1,000-10,000
Equipment running rigidly fixed process	Real-time model-based process control - single module can run at multiple process points
>200 steps to process wafer, e.g.: 76 lithography steps 42 inspections, 34 cleans 24 depositions, 11 etches 9 implants, 5 anneals	All-dry, all rapid thermal processing Simplified lithography for reduced step count No cleans, inspections
≥10% test wafers	No test wafers
35% of equipment time utilized	Full equipment utilization
78-80 day cycle times	Rapid turnaround - days
Manual data entry; 5-10% of data used	Fully integrated CIM to manage complexity - "lights out" factory

920417.06

Elements of an Intelligent, Flexible Manufacturing System

Process Modeling and Optimization

In-Situ Sensing

Application of Advanced Control Theory

FIG. # 15

Elements of an Intelligent, Flexible Manufacturing System

Process Modeling and Optimization

- Simulation based on physics and chemistry
- Models for Process Control
- Process Optimization for Control

FIG. # 1C.

ARPA Elements of an Intelligent, Flexible Manufacturing System MTO

In-Situ Sensing

- Key Product Variables
- Key Process Variables
- State of the Machine

#17

ARPA

Elements of an Intelligent, Flexible Manufacturing System

MTO

Application of Advanced Control Theory

- Multivariable
- Model-based
- Feed-forward / feed-back
- Closed loop

FIG. # 18

ARPA Intelligent Manufacturing MTO

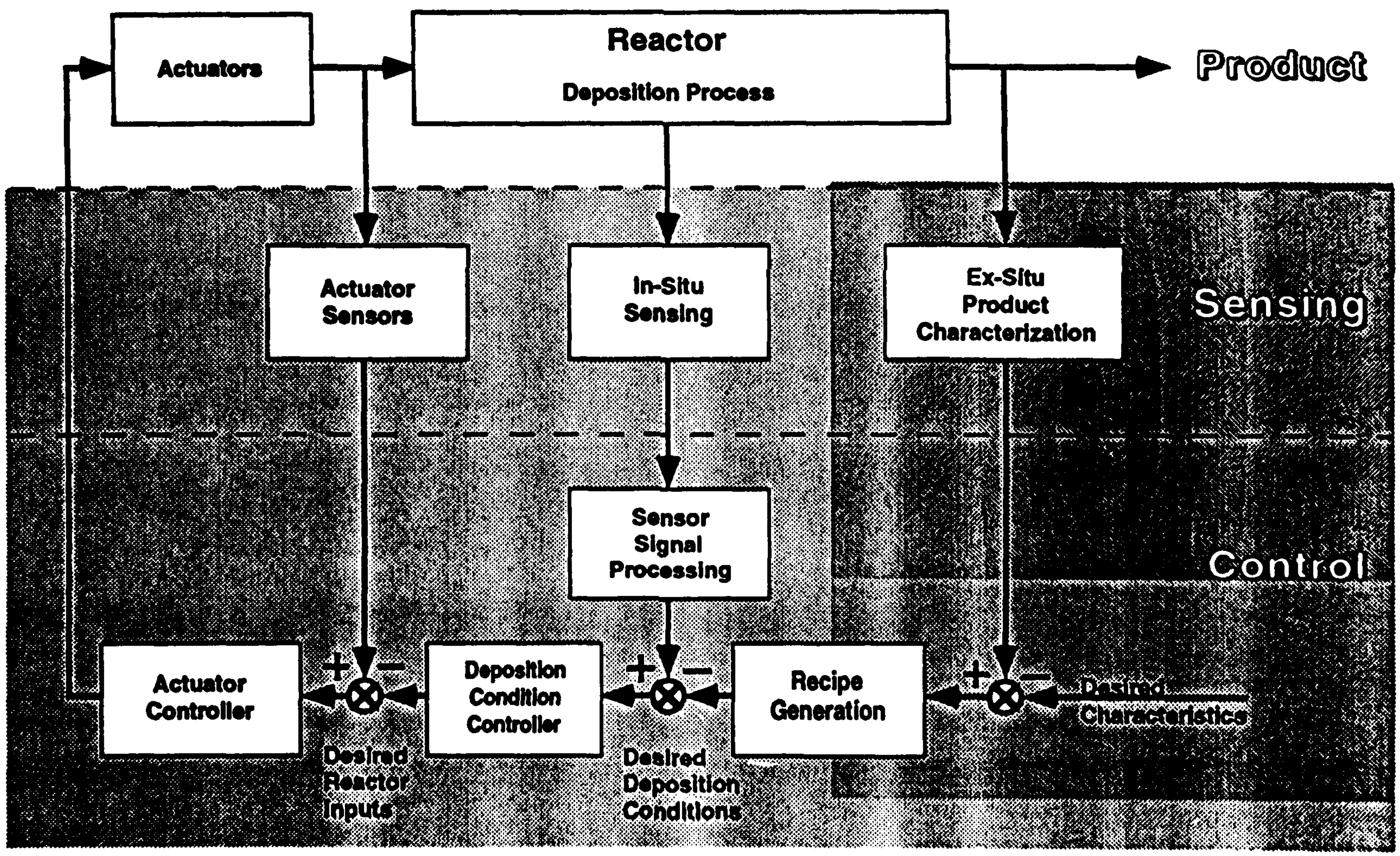


FIG. # 10

MICROELECTRONICS MANUFACTURING SCIENCE AND TECHNOLOGY

Develop revolutionary concepts for flexible semiconductor manufacturing

- Lower semiconductor fabrication facility costs by >10X
- 0.35-micron feature size for moderate volume ASICs
- Flexible, programmable

FY 1988 - 93 (Joint with Air Force)

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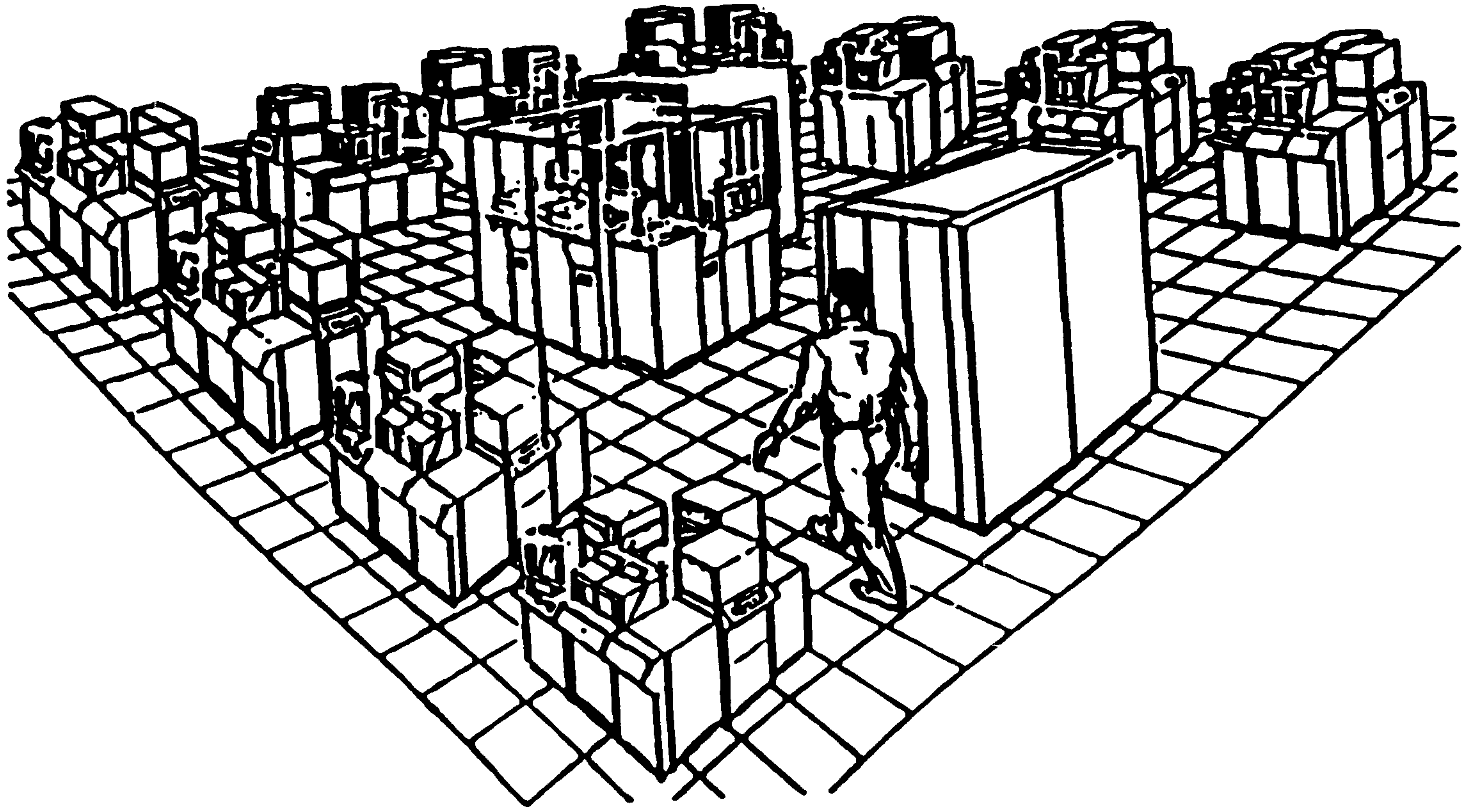
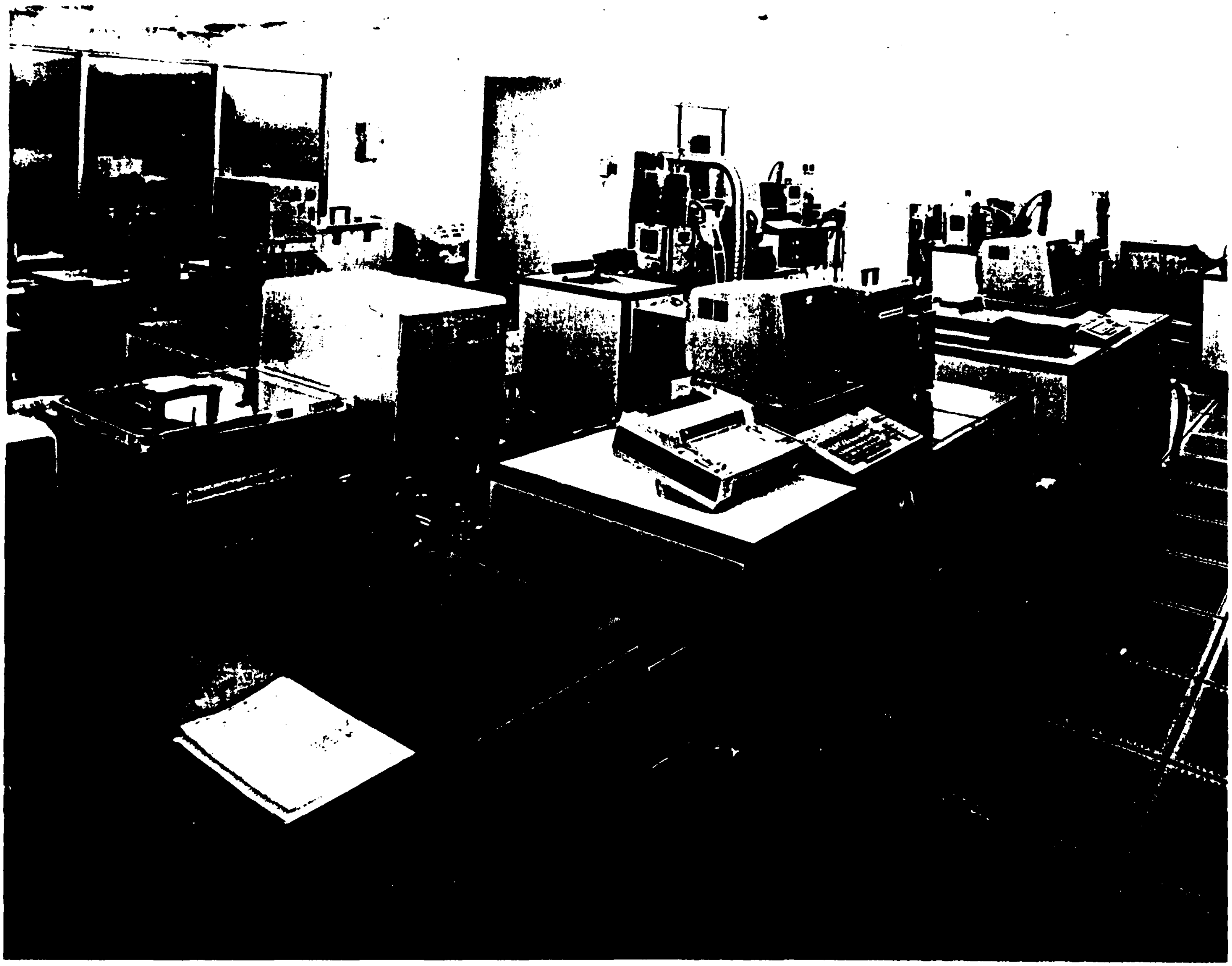
MICROELECTRONICS MANUFACTURING SCIENCE AND TECHNOLOGY (MMST)

Texas Instruments



MMST FABRICATION FACILITY



TEXAS INSTRUMENTS

SEMATECH

Consortium of major U.S. semiconductor companies and ARPA

AMD	Intel	NCR
AT&T	IBM	Rockwell
Digital Equipment	Motorola	Texas Instruments
Hewlett Packard	National Semiconductor	

Mission: Create fundamental change in manufacturing technology and the domestic infrastructure to provide U.S. semiconductor companies the capability to be world-class suppliers

Program Managers:

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David Patterson - Lithography
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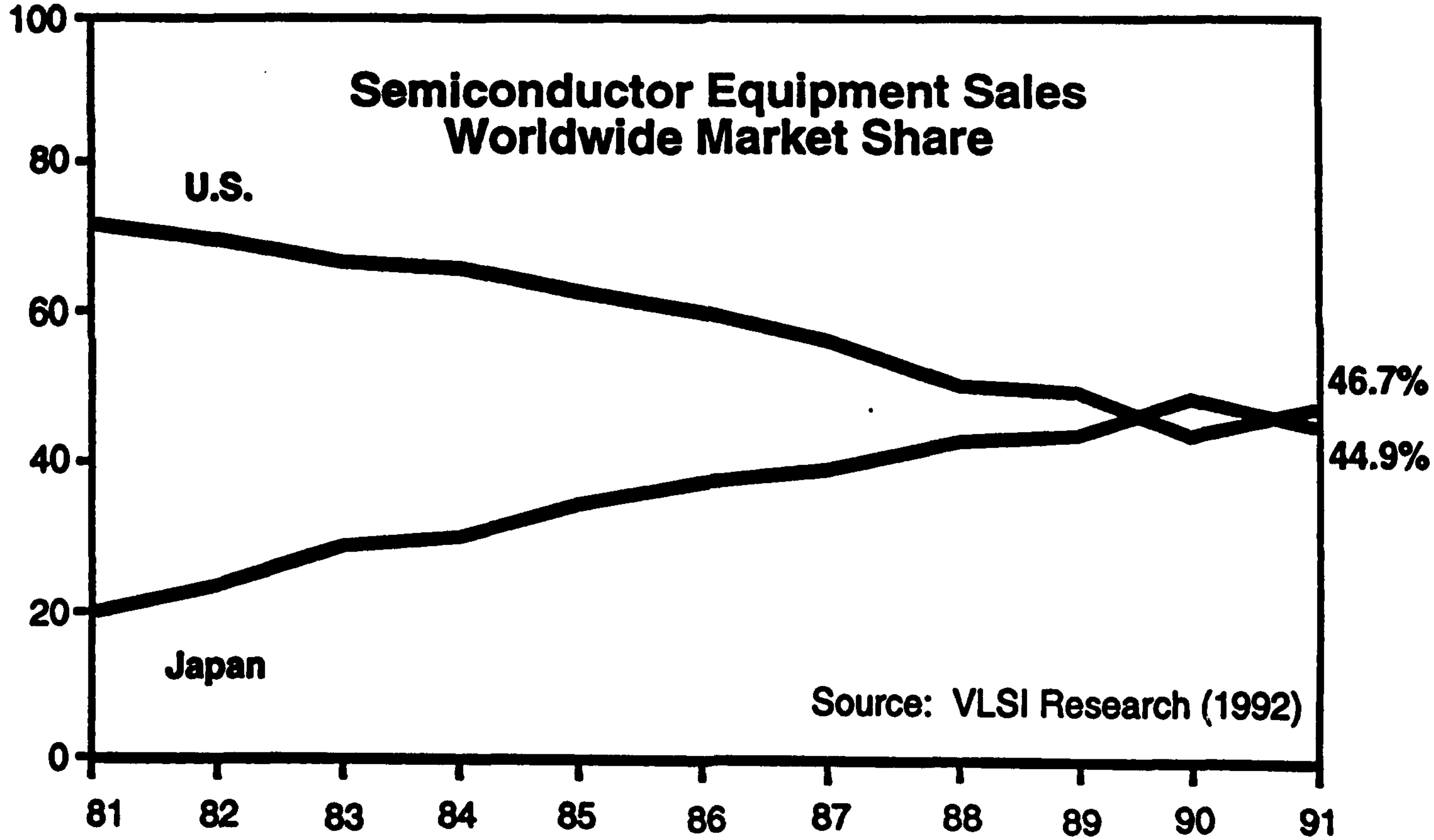
U.S. Chip Equipment Suppliers Reverse 10-Year Decline



"Every way I look at the data I come back to the belief that this has to be a SEMATECH-driven increase."

Jerry Hutcheson, CEO, VLSI Reasearch

930513.01

FIG. #23

WORLDWIDE SEMICONDUCTOR MARKET SHARE

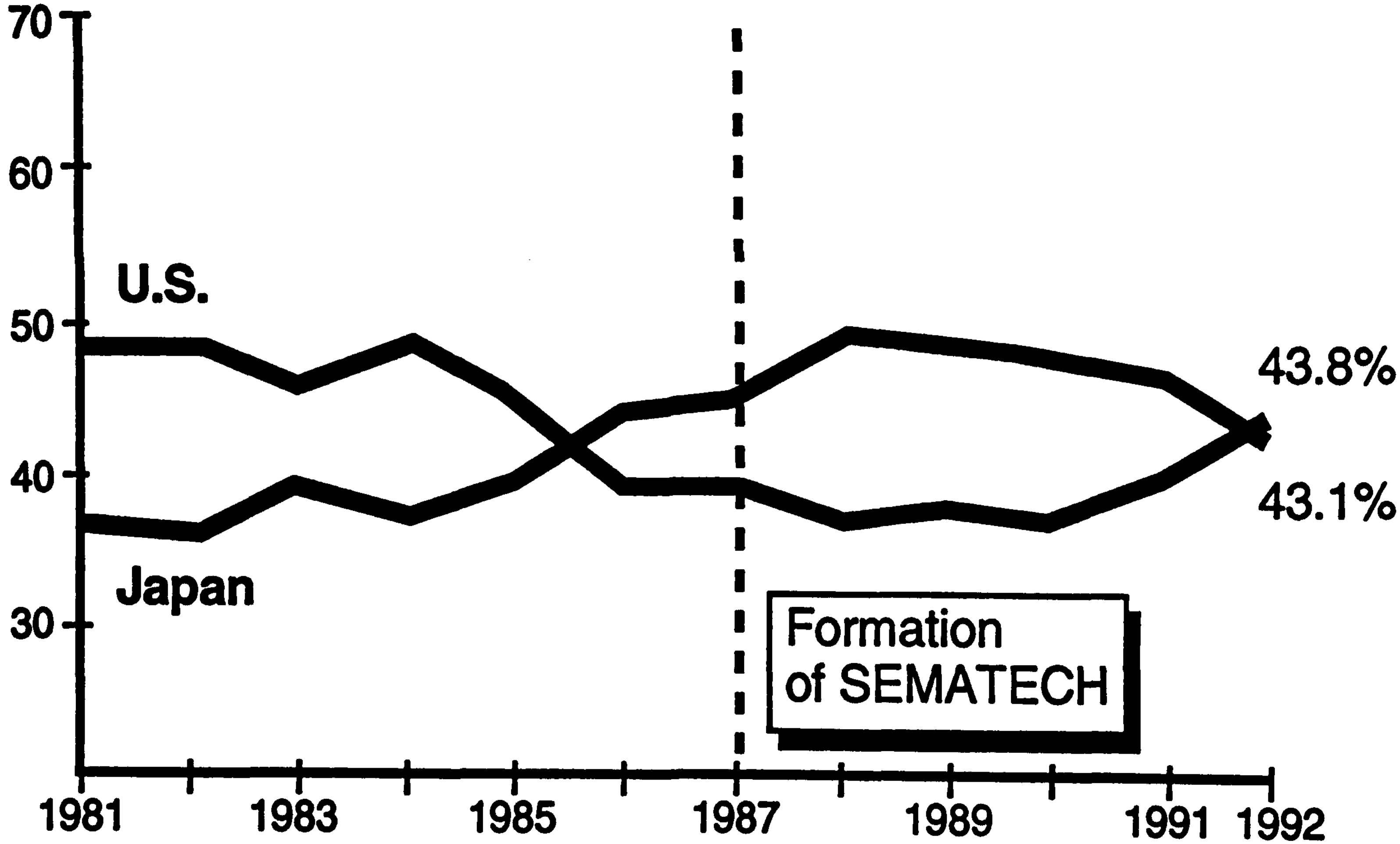


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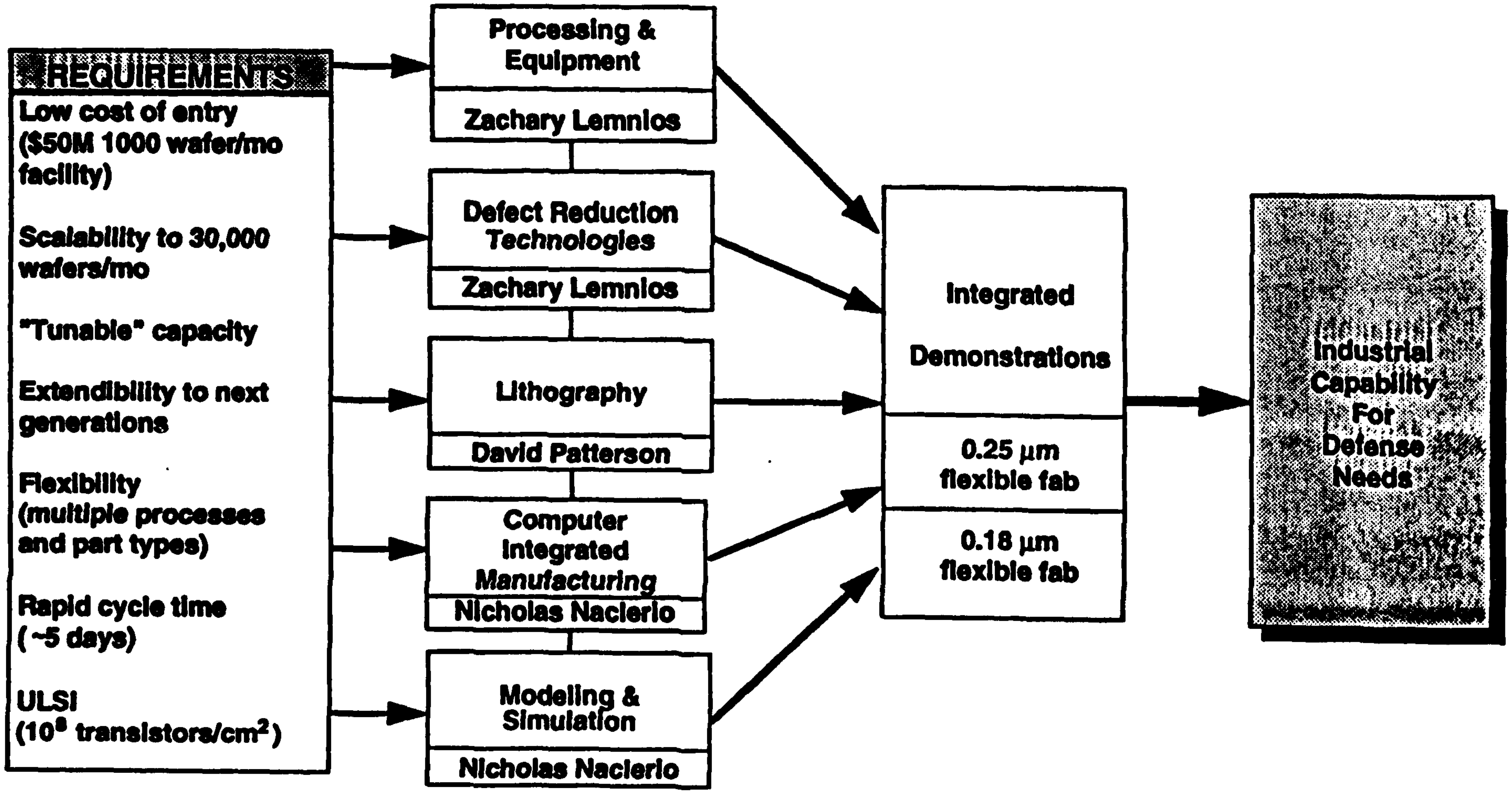
FIG #24

SEMATECH
ARPA FY 1993 - 97 PLAN



ARPA

ADVANCED LITHOGRAPHY

MTO

Develop technologies for lithography tools and processes to fabricate integrated circuits with features of 0.18µm and below

- Crosscutting Technologies
  - Masks
  - Overlay/Alignment
  - Metrology
- Proximity and Projection X-Ray
- Projection Ion Beam
- Projection Electron Beam
- Advanced Optical

FY 1988 - 9~~5~~ 4

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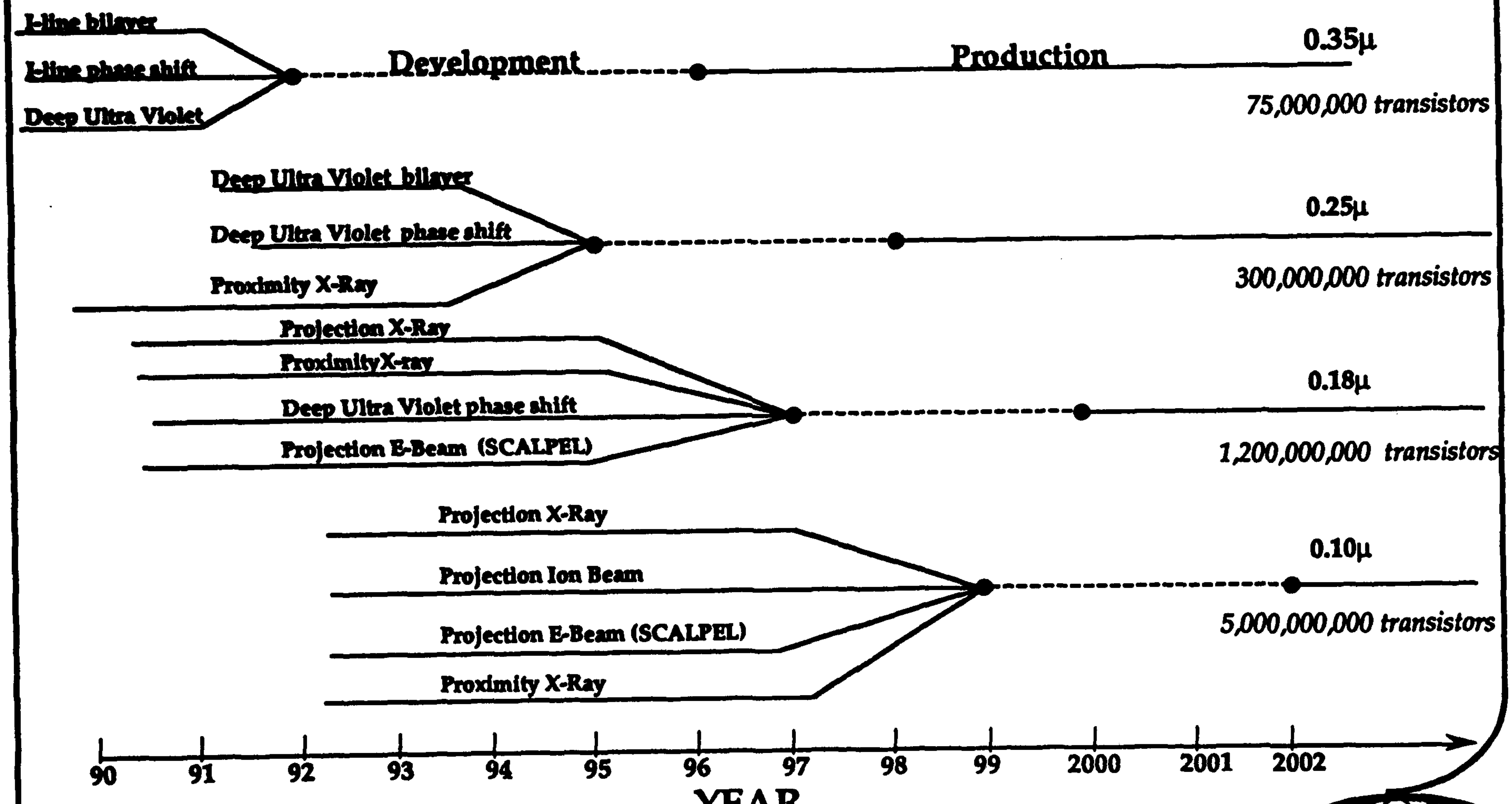
F/G. # 26

ADVANCED LITHOGRAPHY



LITHOGRAPHY TIMELINE

INFRARED FOCAL PLANE ARRAYS

Establish manufacturing base for IRFPA modules with integral signal processing

- Reduce cost by a factor of 100
- Tri-Service systems insertions in missile seekers, target acquisition sights, IRSTs

Research III-V heterostructures with integral processing for multi-spectral sensors

FY 1989 - 97

Program Manager: Ray Balcerak
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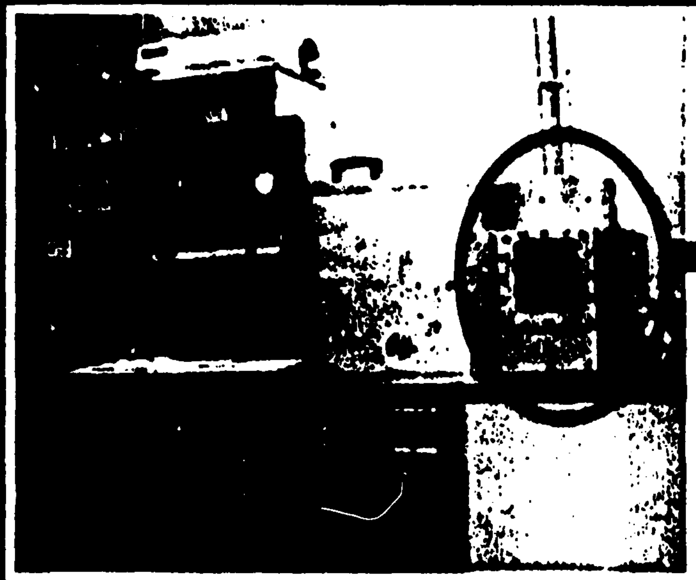
DARPA

ADVANCED VACUUM PROCESSOR (AVP) MODULES



Individual Heads for:

HgCdTe Etch
Cleanup/Passivation/Insulator
Dielectric Deposition
Dielectric Etch
Metal Deposition
Metal Etch

- Based on dry-processing modules developed for MMST
- Scalable production ⟶ low cost FPA's in both low and high volume production
- Cassette-to-cassette sample handling
- IRFPA configuration independent
- Interchangeable heads for process flexibility

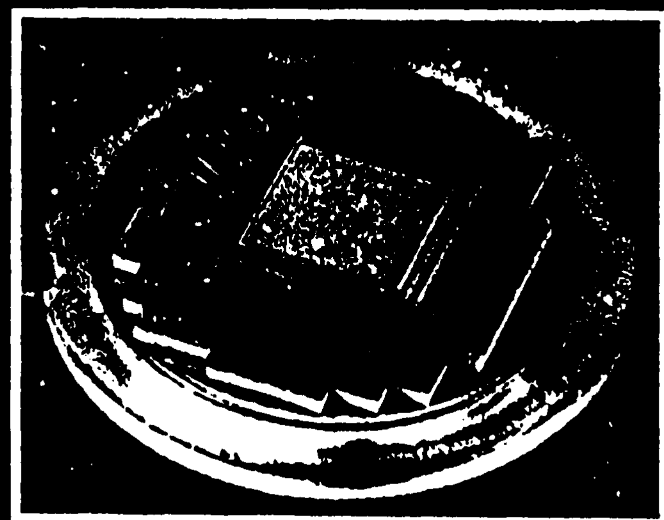


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FIG 2C

ARPA

MTO STRATEGIC GOAL

MTO

Create dramatic advances in technology and stimulate fundamental change in industrial capability in critical aspects of microelectronics technology

Microelectronics Beyond Digital Silicon:

Research, develop, demonstrate, and transition ***key component technologies to overcome performance barriers*** in interconnect, computing, front-end processing, and interfaces.

Microelectronics Manufacturing:

Advance and implement ***manufacturing equipment and methodologies that create flexible capability*** for low-cost access to small volumes of high-value-added microelectronics.

IR Focal Plane Arrays:

Develop and implement ***IRFPA device and manufacturing technologies*** to meet DoD's varied, ebb-and-flow demands for a technology driven by defense needs.

921017.17

IV-C FLEXIBLE MANUFACTURING OF INFRARED FOCAL PLANE ARRAYS

MR. RAYMOND S. BALCERAK

FLEXIBLE MANUFACTURING
OF
INFRARED FOCAL PLANE ARRAYS

Sixteenth Advanced Research Projects Agency
Systems and Technology Symposium
June 22-24, 1993

Raymond S. Balcerak
ARPA/MTO

93-S-2080

CHART 14

All infrared sensor products produced in the ARPA Program will utilize the flexible approach to infrared focal plane arrays manufacturing. The specific devices discussed in this paper include the two color sensors used for infrared search and track, an integrated two color infrared sensor, and a large area staring focal plane array.

CHART 15

Arrays with sensitivity in multiple spectral bands will be required for many systems. The example shown in this chart is a shipboard search and track system, which will utilize ARPA sponsored IRFPA technology. This is an immediate application of the flexible manufacturing approach since arrays with different material composition require variations in processing technology. In addition, the electronics sampling required may vary depending upon the targeting requirements. A flexible manufacturing approach is necessary to accommodate for these differences in spectral sensitivity and electronics design, producing arrays in a reasonable time frame, at affordable cost, meeting system specifications.

CHART 16

Another unique applications of flexible manufacturing is the capability to detect multiple spectral bands in the same array structure. This compact array structure can be used for missile seeker applications, and in advanced infrared search and track systems. Commercial applications which require real-time identification gas spectra can also take advantage of this integrated multi-spectral structure. The control of material and device fabrication parameters in the flexible factory environment are necessary to realize these advanced device structures.

CHART 17

As a final example of new array architectures, the large area staring array with television compatible format is shown. This large array permits integration into both air and ground vehicles. These systems are not possible without a flexible approach to producing these large array designs. Precise control of manufacturing parameters over large area wafers is essential to realize these advanced structures.

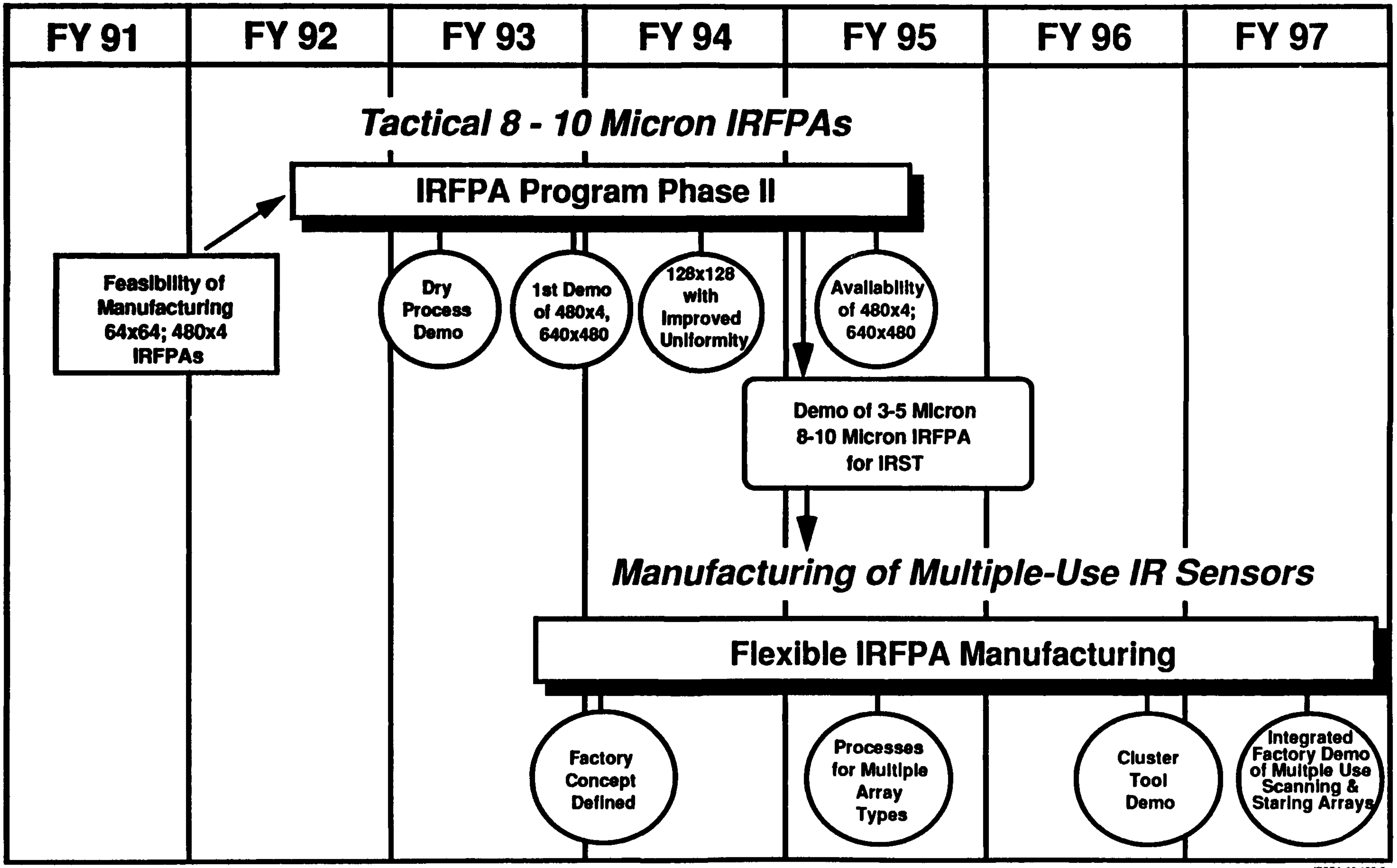
CHART 18

This chart shows the 480x640 array being produced under the ARPA IRFPA Program. Arrays are now being tested. These arrays are built on both silicon and cadmium telluride substrates.

CHART 19

SUMMARY

INFRARED FOCAL PLANE ARRAY PROGRAM



IRFPA-93-135-2

FLEXIBLE MANUFACTURING OF INFRARED FOCAL PLANE ARRAYS

- IR Sensor Application Base
- Brief Description of Manufacturing Process
- Flexible Manufacturing Technology
- Future Sensor Concepts

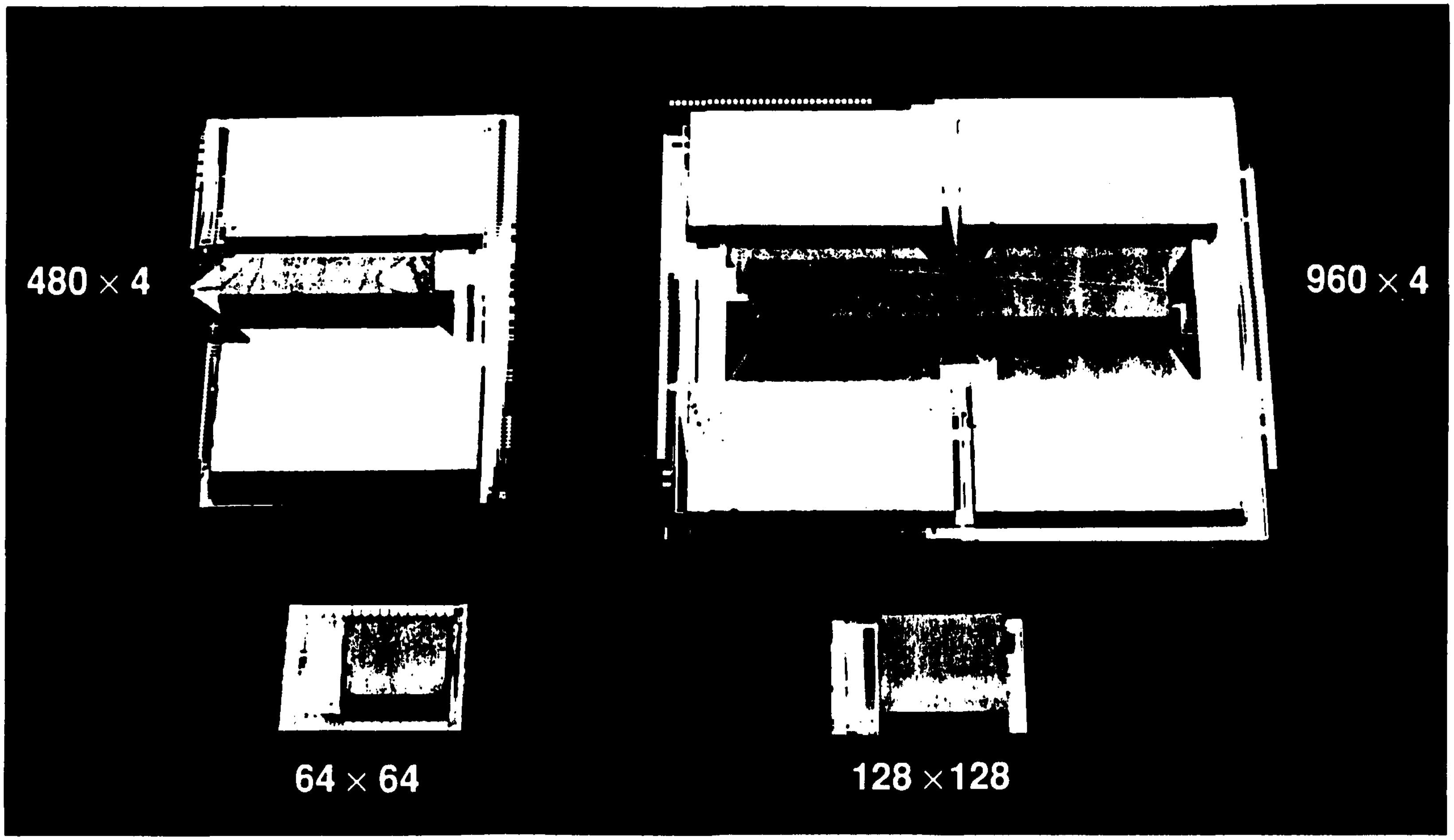
IRFPA-93-135-2

FLEXIBLE SEMICONDUCTOR MANUFACTURING

Objective

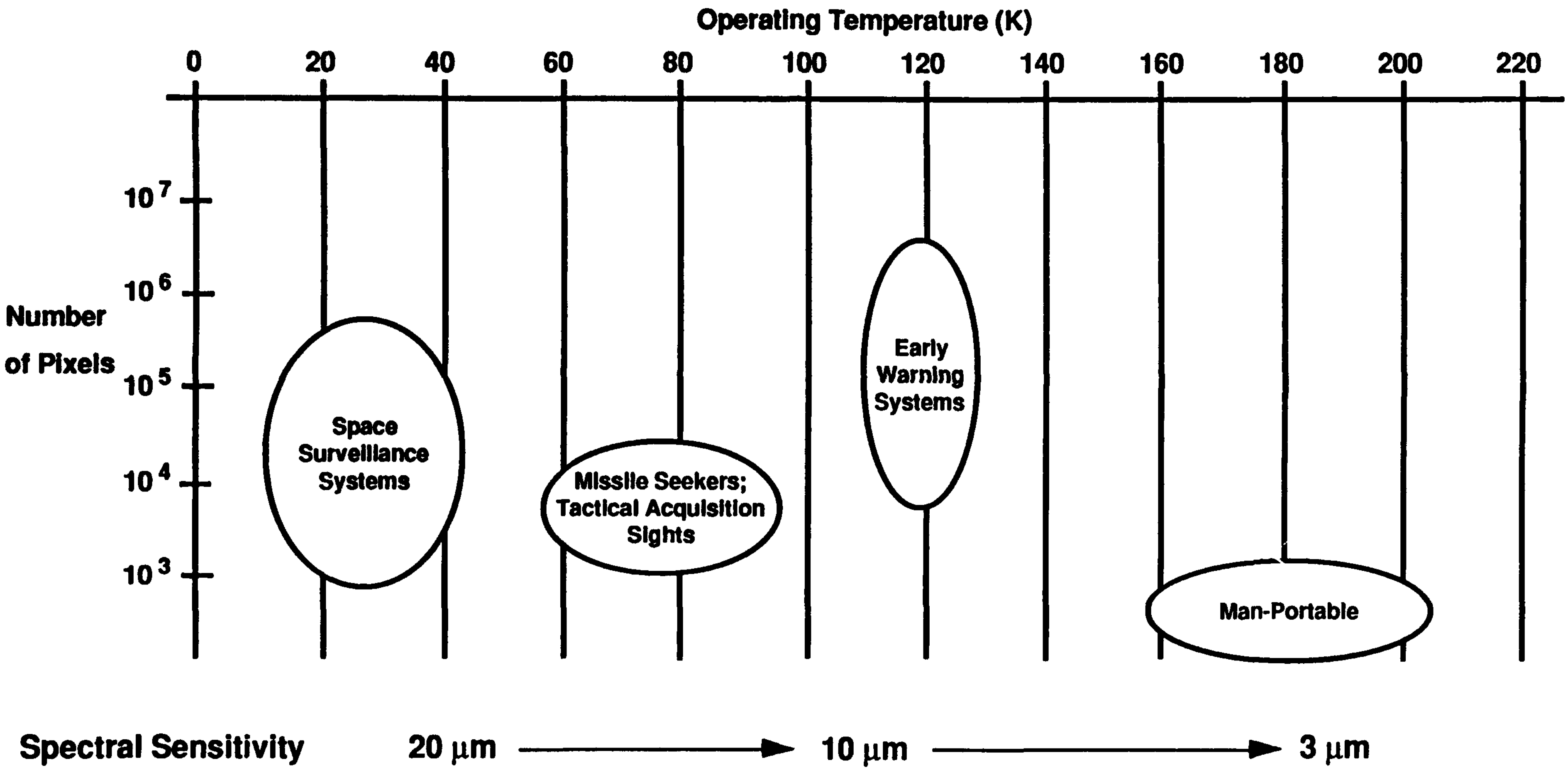
Capability to produce a wide range of semiconductor devices with high yield, idependent of production volume, and rapid cycle time through the manufacturing line.

TACTICAL LWIR
FOCAL PLANE ARRAY ASSEMBLIES



IRFPA-93-135-4

IRFPA APPLICATIONS BASE



IRFPA-93-135-5

DUAL APPLICATION AREAS OF IR SENSOR TECHNOLOGY

IR Sensor Type	Application Areas: Vehicle Systems	Aircraft Landing Aid	Wind Shear Detec.	Man. Process Control	Drug Enforcement	Environ Monitor
Uncooled	●			○	●	
TE Cooled	○	○			○	
Mid-Wave						
LWIR		○	○			○
Multi-Spectral			○	○		●

● = Near-term insertion

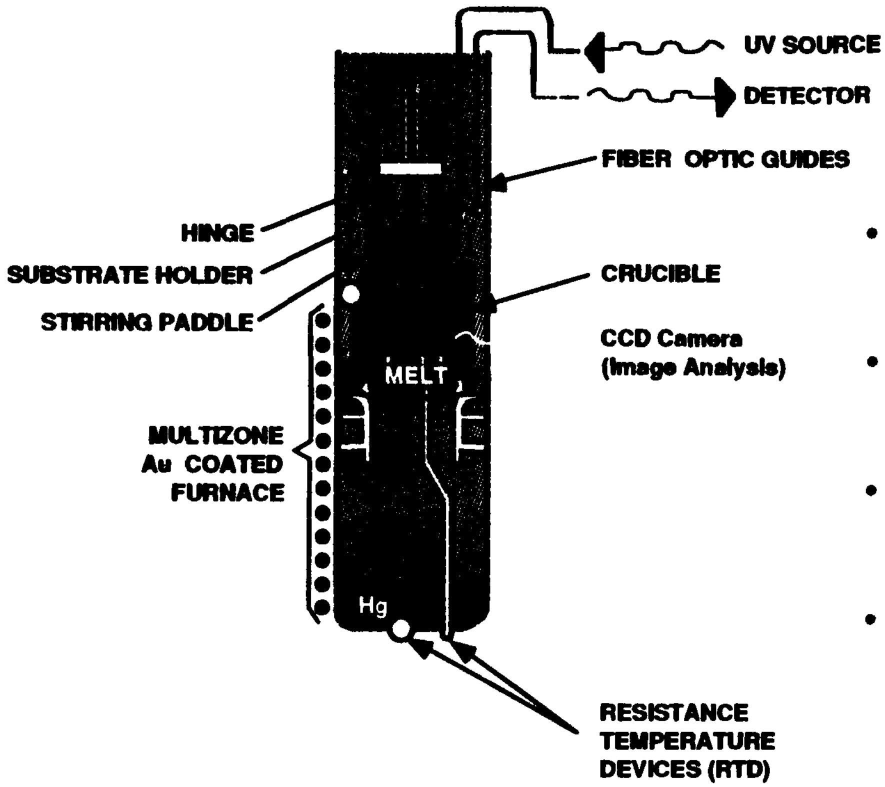
○ = Applications being investigated

IRFPA-93-135-6

FLEXIBLE MANUFACTURING PROCESSES FOR IR FOCAL PLANE ARRAYS

Process		Manufacturing Flexibility
• Material Growth	→	Spectral Selectivity
• Etching	→	Pixel Size; Array Configuration
• Metalization	→	Material Compatibility Reliability
• Read-out/Command & Control Electronics	→	Adaptability to System Parameters
• Assembly	→	Reconfigurable, Low-cost Package
• High Throughput Testing	→	Multiple Product Qualification
• Computer Integrated Manufacturing	→	Product Flow; Workstation Control

SENSOR BASED HgCdTe LPE GROWTH

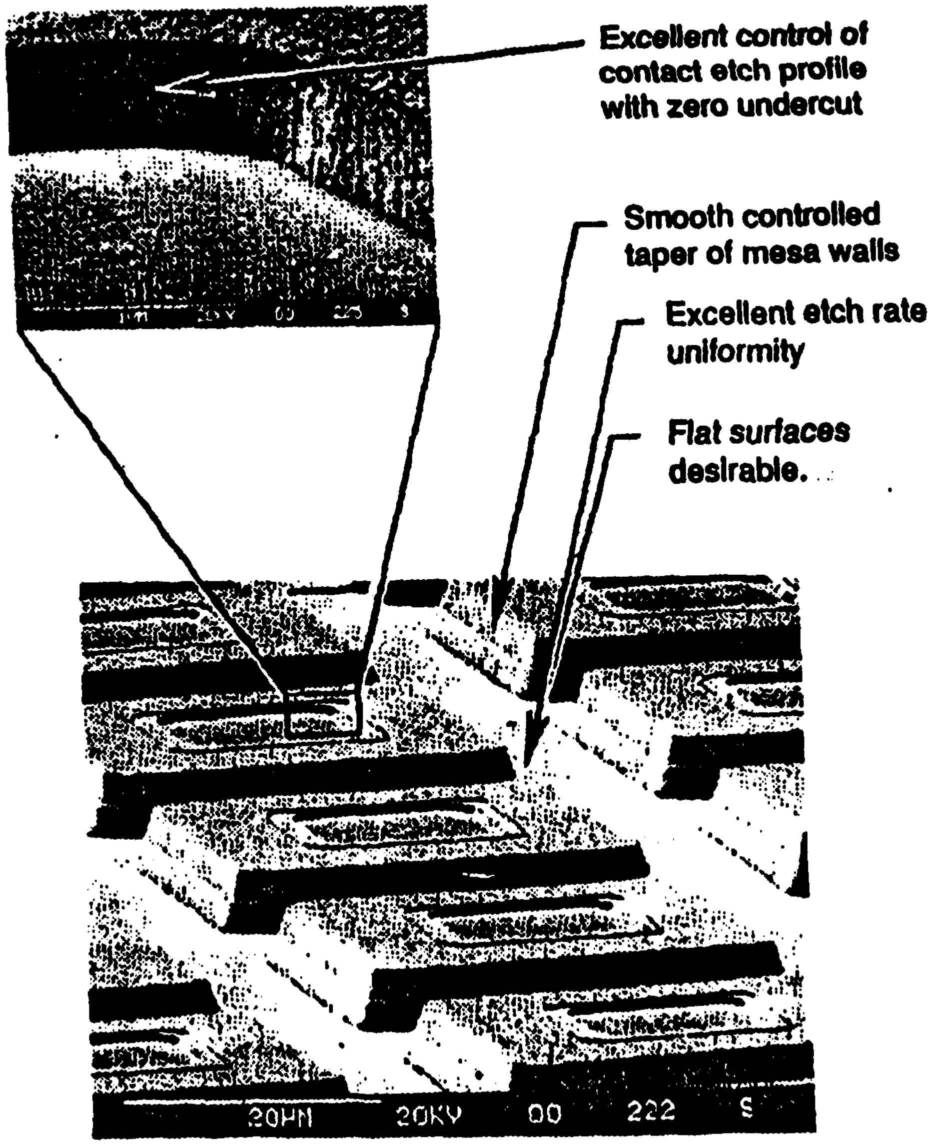


- Optical Hg partial pressure monitor-melt composition control
- CCD camera-liquids temperature determination
- RTD temperature control-film thickness control
- Electron microprobe-film composition measurement

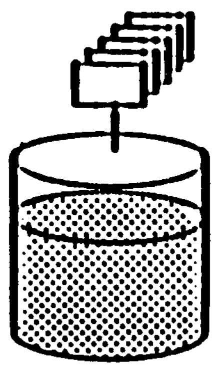
IRFPA-93-135-8

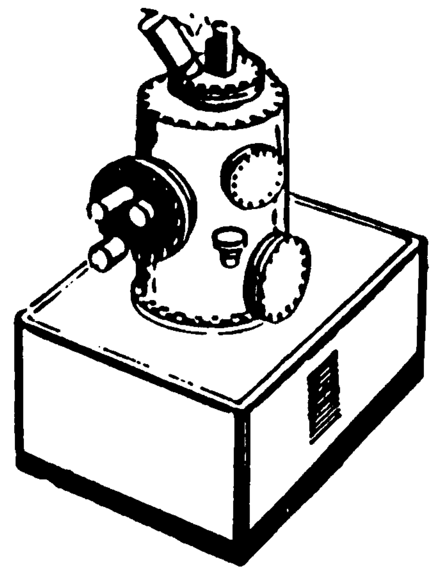
DRY ETCHING OF INFRARED DETECTOR ARRAYS

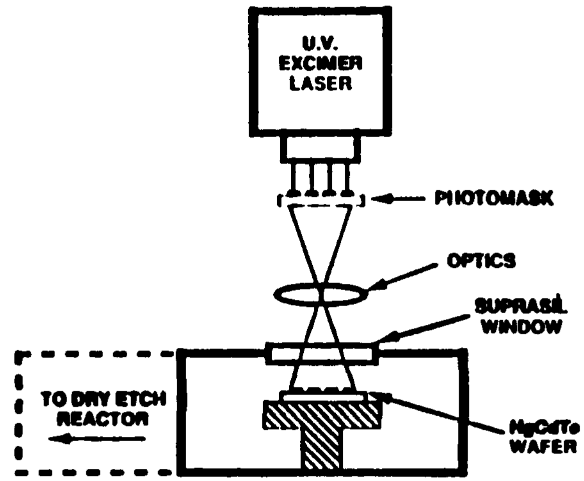
- Geometrical control possible with dry processing
- Electrical performance meets system requirements



IRFPA MANUFACTURING MODULE







Current Process Sequence

- Material passed manually between processes
- Potential for contamination and handling damage
- Process repeatability and yield are subject to process technician variables

Dry Process Module

- Material etching, characterization, and passivation performed in an integrated module
- Passivation applied after in-situ characterization
- Etching/passivation module can be integrated with other modules to form a repeatable high-yield production process

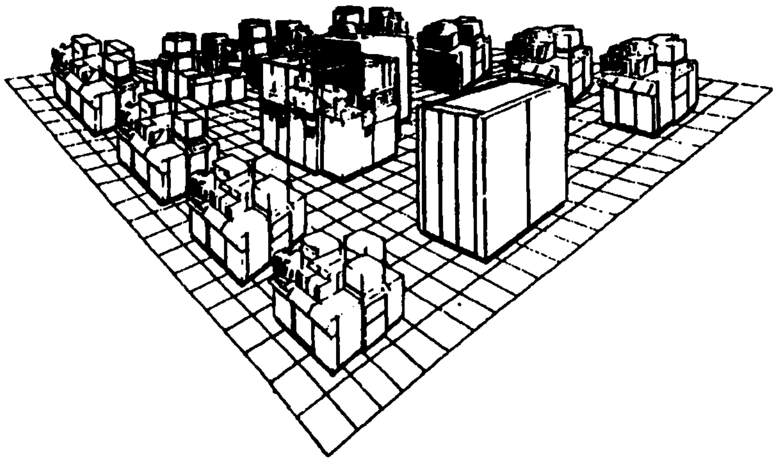
Long-term Process

- Vacuum in-situ patterning
- Laser process chamber will interface to dry etch reactor

IRFPA-93-135-10

IRFPA WAFER FABRICATION CONCEPTS

Modular Wafer Fabrication Facility
Concept from the Silicon IC Industry



Application of Modular Fabrication Facility to IRFPAs

- Designed for moderate volume rapid cycle time, multitechnology wafer processing
- Incremental capacity addition
- Clean room in the equipment
- Common modular equipment for flexibility and low cost
- Multiple processes brought to the wafer
- Fully computer integrated to run multiple designs and configurations
- Process control via in situ sensing, feedback and feed forward
- Artificial intelligence and expert system computing

m93-1431-01

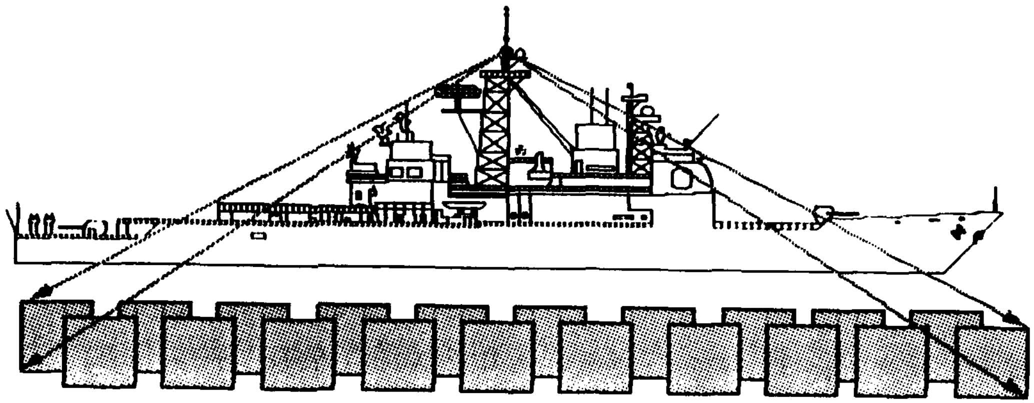
DUAL-BAND IR SEARCH AND TRACK SYSTEM

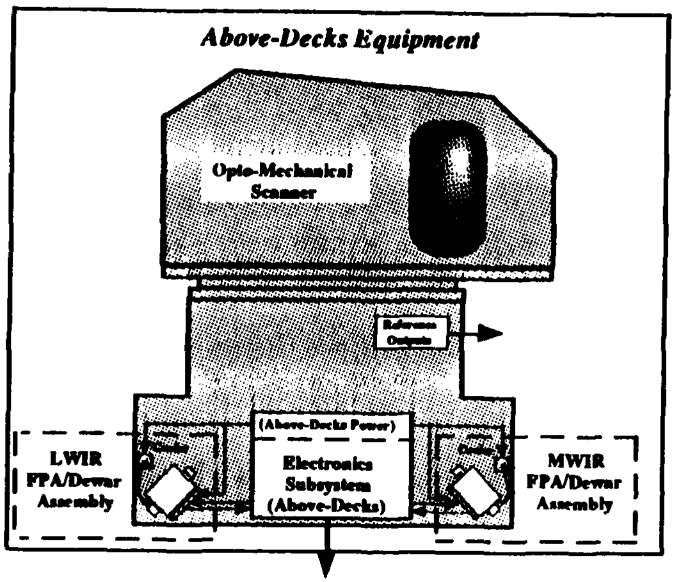
New IR Sensor Products

- 2 - Color Search and Track
- Integrated Multi-Spectral Array
- Large Area Long Wavelength Staring

DUAL - BAND IR SEARCH AND TRACK SYSTEM

- Employs IRFPAs Sensitive in Both 3 - 5 and 8 - 10 μm Bands
- Variable Sample Density
  - LWIR
  - MWIR



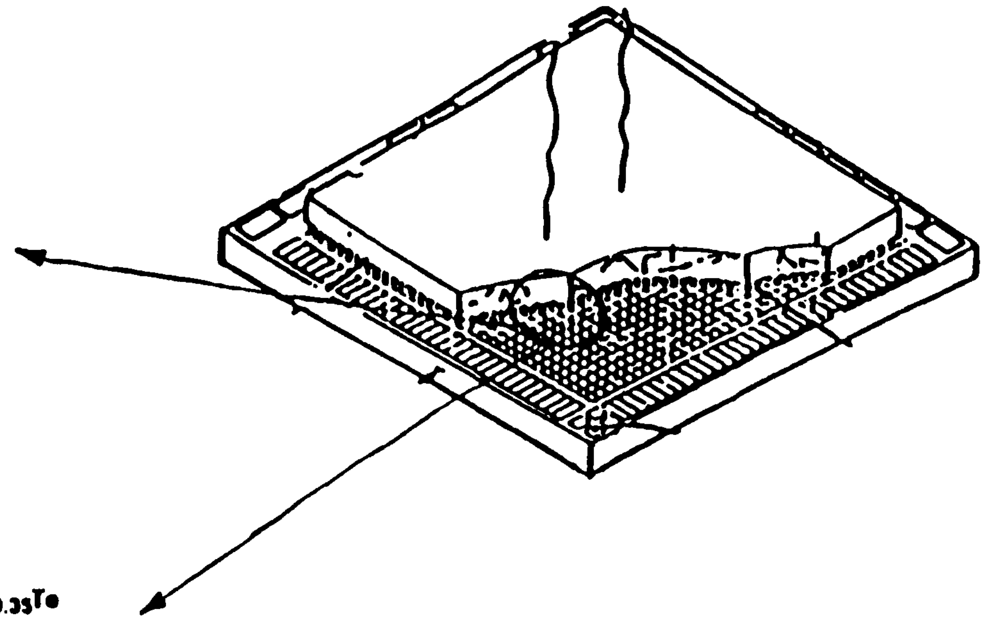


- 360°/sec Horizon Search and Track
- Passive Infrared Sensor
- MWIR 3 - 5 μm and LWIR 8 - 12 μm
- Real-Time Signal Processing
- System Demo in FY95

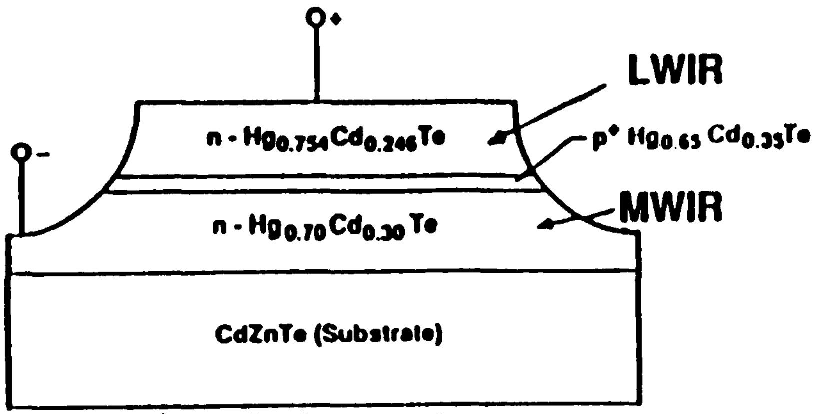
IRFPA-93-135-6

FUTURE IR SENSOR REQUIREMENTS

- Selectable sub-bands within the primary band
- First level discrimination on the focal plane
- Detector interface compatible with several IR bands



<u>Signal Processor</u>



Bias Selectable Photodiodes

<u>Approaches to Unit Cell</u>

<u>Integrated MS Detector/Signal Processor</u>

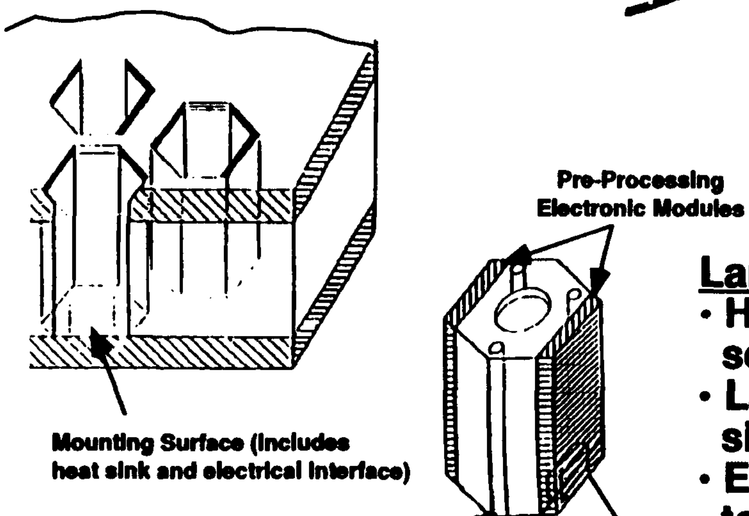
- Multi-layer epitaxial growth for flexible spectral discrimination
- Signal Processing integrated into the detector array
- Pixel-to-pixel registered multi-spectral detection

IRFPA-93-135-16

AIRBORNE MULTIFUNCTION IR SENSOR

(Based upon 640 x 480 IRFPA II Development)

- Multifunction sensor
  - Navigation/situation awareness
  - Missile warning
  - IR search and track
- 640 x 480 MW and LW IRFPAs
- Large FOV
- Up to 1000 frames/second



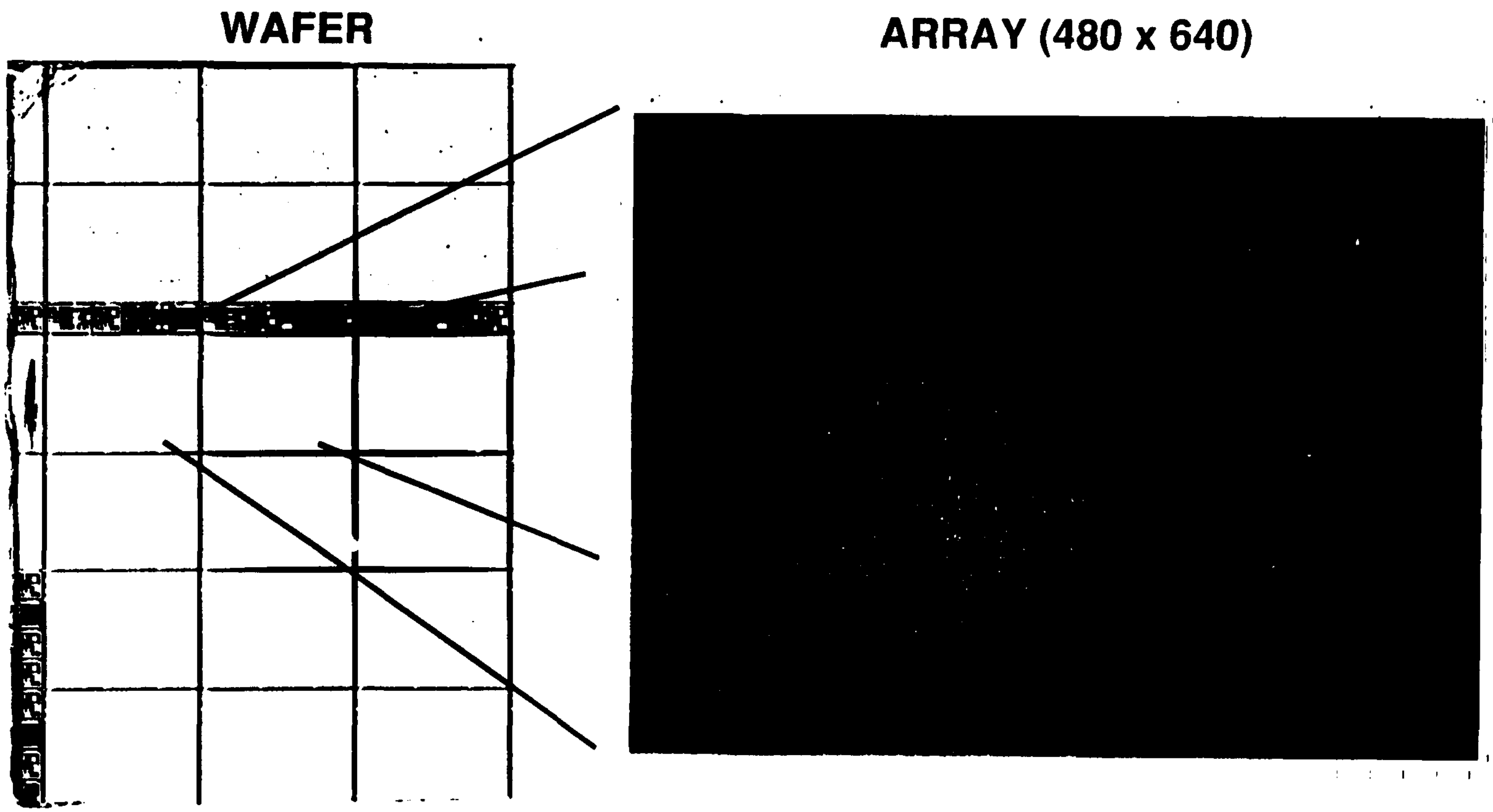
Aircraft Skin Installation

Large Area Staring Array Implementation

- High speed data link for multiple sensors
- Large staring array reduces aircraft signature and improves reliability
- Electronic module directly interfaced to sensor (parallel processing)

m93-3094-01

LARGE FORMATE STARING IR FOCAL PLANE ARRAY



480 X 640 LWIR Array Being Developed by IRFPA Program

FLEXIBLE MANUFACTURING OF INFRARED FOCAL PLANE ARRAYS

Summary

- IRFPAs are essential to a broad range of defense, and potentially, commercial applications.
- Flexible manufacturing is essential to a low-volume, specialized semiconductor product, the IRFPA.
- In-situ sensors, real-time feedback control, and integrated factory management systems are key technologies to flexible manufacturing.

IV-D ELECTRONIC SYSTEMS

DR. LANCE A. GLASSER

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ARLINGTON, VA 22203-1714

August 3, 1993

MEMORANDUM FOR ESTO - GLASSER

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

Reference is made to the following material submitted for clearance for open publication:

ELECTRONIC SYSTEMS

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CC: K. Pulzone

INTRODUCTION TO ELECTRONIC SYSTEMS AT ARPA

Viewgraph 1: Introduction

Viewgraph 2:

Electronics at ARPA are principally the function of the Microelectronics Technology Office (MTO) and the Electronic Systems Technology Office (ESTO). Three principle electronic areas under development at ARPA are Microelectronics; Electronic Modules and Systems; and Sources, Sensors, Actuators, and Displays.

Microelectronics includes microelectronics manufacturing (i.e., SEMATECH, MMIS, Lithography), semiconductor process synthesis, optoelectronics for information processing, ultra-dense ultra-fast computing components, and HBT A/D converter technology.

Electronic Modules and Systems include electronic packaging and interconnect (EP\I), embedded microsystems, and signal processing (RASSP).

Sources, Sensors, Actuators, and Displays includes high definition systems (HDS), infrared focal plane arrays, and microelectromechanical systems.

Viewgraph 3:

The strategic thrust of ESTO is electronic systems technology for smaller, lighter, more mobile information systems. ESTO pursues technologies which advance sensors, sources, actuators, and displays; signal processing where the signals are; manufacturing and precision assembly; electronic packaging and interconnect; and low-energy computing and wireless communications.

Viewgraph 4:

ESTO technologies include Microwave & Millimeter Wave Integrated Circuits (MIMIC), High Definition Systems (HDS), Application Specific Electronic Modules (ASEM), Physical Electronic Packaging, Rapid Prototyping of Application Specific Signal Processors (RASSP), Embedded Microsystems, and Microelectromechanical systems (MEMS).

MIMICs are solid state circuits that receive, transmit, and process microwave signals. They are the sensors, or "eyes and ears," of equipment operating at microwave (and millimeter wave) frequencies. MIMICs can either amplify received signals and send them to the digital processing portion of a system or transform digital information into microwave signals to be transmitted by an antenna. The goal of the MIMIC program is to provide affordable, reproducible, and reliable "front end" components and subsystems for DoD systems such as smart weapons, radar, communications, and electronic warfare.

The **HDS** program focuses on getting information out of computers and databases and into people's minds, enabling improved decision making in time-constrained environments. It will move the DoD from information-poor interactions, such as grease pencils and acetate, to information-rich interactions, such as flat-panel displays that provide windows into High Performance Computing and Communications (HPCC) resources. The program encompasses the development of a wide variety of technologies associated with high definition systems including displays, display processors, sensors, software, high density storage, packaging, and manufacturing. The program's overall goal is to achieve a design and manufacturing capability that can provide for and sustain the affordable use of high definition technology in DoD systems in the late 1990s and beyond. The program is a unique experiment in trying to get back a field that has been lost.

ASEM program will ensure the existence of an end-to-end capability to rapidly acquire electronic modules and subsystems. In addition to integrating the key capabilities of design, manufacturing, and test, the program also addresses the information technologies and infrastructure needed for rapid acquisition. The program integrates and builds on the domain-specific building blocks such as physical packaging technology, packaging computer-aided design (CAD), flexible manufacturing processes and equipment, computer-integrated manufacturing (CIM), intelligent test, and design, interface, and test standards.

The **Physical Electronic Packaging** program is developing MCM technology for digital systems operating at clock rates from 100 MHz to several GHz. With MCMs, bare chips are interconnected via a common substrate instead of packaging each chip individually in single-chip carriers. This approach offers increased density and reduction in electrical parasitics. For system clock rates exceeding 50 MHz, conventional chip-to-chip interconnects can significantly negate system performance improvements derivable from advances in devices and circuits. In addition, MCM technology offers the potential of 10-100X improvements in density, as much as 2-3X reduction in power, 10X improvement in reliability, and reduced cost. Applications are tri-service, including, for example, satellite electronics, advanced workstations, smart munitions, avionics, man-portable devices, and autonomous underwater vehicles.

The goal of the ARPA/tri-Service **RASSP** program is to dramatically improve the process by whicn complex digital systems, particularly embedded signal processors, are specified, designed, documented, manufactured and supported. A further goal is to exploit, further develop and integrate emerging technologies to establish state-of-the-art performance and reliability. The domain of embedded signal processors has been chosen because of its importance to a wide variety of military and commercial applications as well as for the challenge it presents in terms of complexity and performance demands. The principle metrics targeted by the program are product cycle time, life-cycle cost, and product quality. Quality will be measured in terms of absence of defects, conformance to requirements, and fitness for use. Performance, reliability, producibility, and supportability are examples of parameters that affect a signal processor's fitness for use. A key objective is to reduce the total product development time by at least a factor of four while making a similar improvement in product quality. The effective incorporation of manufacturing and life-cycle requirements early in the design process will be an important aspect of the quality effort. Also important will be the ability to insert the latest available technology at system build time and to incrementally

upgrade the system throughout its life-cycle. The program has adopted a MODEL YEAR methodology as a way of stressing the importance of continuous improvement, meeting short development schedules (3 to 12 months), and avoiding point design solutions. The MODEL YEAR methodology states that systems should be upgradeable on an annual basis, with increasing function and performance. It is expected that most of the results of the effort will be generalizable to other classes of electronic systems.

The **MEMS** program pursues several technologies including embedded microsystems, microdynamical systems, and conformal electronics that support mobile information systems. Advancing these technologies will result in a revolution in the perception and control of the environment. Embedded microsystems target advanced signal processing with special emphasis on techniques that minimize energy dissipation to increase the computing power that can be supported by small batteries. Microdynamical devices include microsensors and actuators, micromechanical accelerometers, miniature analytical instruments, mass data storage devices, miniature mass spectrometers, thermo-pneumatic microvalves, and micropumps. Potential applications for these devices include distributed unattended microsensors for ground surveillance, unobtrusive biomedical sensors, and personal inertial guidance units to augment the Global Positioning System (GPS).

Conformal electronics involve packaging technologies for shape-constrained environments. These components must conform to, rather than dictate, the system form factor.

Viewgraph 5:

During the first three years of hardware development, which began in May 1988, improved gallium arsenide material was developed and made available. Computer-aided design, fabrication, and test capabilities were substantially extended. Integrated, high-throughput manufacturing facilities were installed. Fabrication recipes were refined and demonstrated to result in high-yield MIMIC chips. New techniques have greatly reduced the cost of packaging and testing MIMIC chips. Over 80 MIMIC chip types were fabricated and demonstrated in 16 MIMIC brassboards. In the next three years, the program is expected to complete the development of fully integrated design, manufacturing, and testing capabilities that can produce, inexpensively and rapidly, the full range of advanced microwave/millimeter wave circuits required for systems.

Viewgraphs 6 and 7:

In Operation Desert Storm, MIMICs were used in both the HARM missile and in LANTIRN's terrain following radar system. Other systems such as the AN/ALQ-136 will retrofit MIMIC hardware into existing modules and subsystems to reduce costs, increase unit-to-unit reproducibility, achieve higher reliability, and improve component performance. Most importantly, MIMIC is an enabling technology for many systems; without MIMIC it will be impossible to field these systems at an affordable cost. Some of these systems are **GEN-X, LONGBOW, MOFA, SADARM MLRS/TGW, AMRAAM,** phased array radars for airborne applications and phased array electronic warfare systems. The MIMIC program represents a national asset and provides an excellent return on the investment made by the Department of Defense.

Viewgraphs 8 and 9:

The physical packaging program has two main thrusts: (1) establishment of merchant foundries capable of low-volume (several hundred per month) production of MCMs for 100 MHz and greater operation and demonstrations in applications, such as parallel processors for the HPCC program, and (2) development of materials, processing, testing, and simulation for 3-D and GHz clock-rate MCMs. Technologies include diamond-based 3-D MCM structures, optical testing, flip-chip conducting adhesive chip attachment, high-speed membrane probe testing, ferroelectric materials for decoupling capacitors, very low dielectric constant materials for GHz signal planes, full wave electromagnetic simulation, laser writing for MCM rework and prototyping, and optical MCM-MCM interconnect. This program is increasingly focusing on high-speed mixed analog-digital and digital-optical modules.

These viewgraphs illustrate the advances made in physical packaging. The top card contains 3 digital signal processors operating at a respectable 40 MHz. The bottom photo is a multichip module containing 4 digital signal processors operating at 90 MHz.

Viewgraphs 10-12:

The goals of **ASEM** are to produce an order-of-magnitude reduction in manufacturing cost, development of a domestic supplier infrastructure, and acceleration of the acceptance and insertion of advanced multi-chip integration technologies.

Despite doubling of IC density roughly every 18 months, there is a continuing need to cost-effectively interconnect multiple dies without substantially affecting performance, volume, weight, or reliability. Since conventional single-chip packages and printed circuit board technology have not kept pace with advances in IC performance and density, implementing many next-generation products in the computing, communications, automotive, and defense markets is difficult or expensive. As a result, alternative approaches such as multi-chip modules (MCMs) have emerged as a way to close the gap. Although the potential for these technologies has been demonstrated, widespread acceptance by systems users has been slow due to perceived risks and high costs.

ASEM will develop the key manufacturing equipments, materials, and processes necessary to manufacture, assemble, and test complete modules that meet the demands of the appropriate marketplace. Cost-effectiveness and environmental awareness will be key concerns in developing this capability. Furthermore, the program will stimulate market demand by demonstrating successful insertions of this technology into current products on the market.

Viewgraph 13:

The RASSP program's objective as to dramatically improve the process by which complex digital system, particularly embedded signal processing are designed, manufactured, upgraded, and supported. This will provide affordable embedded signal processors for a wide range of systems that state state-of-the-art when fielded, not just when designed. Although targeted only at embedded real-time signal processor, RASSP draws upon a broader base of supporting design technology. Many RASSP results are expected to be extendible to other types of electronic design.

Viewgraph 14:

Information technology continues to move rapidly. This state-of-the-art has two trends: toward more mobile, more ubiquitous computing, and toward massive teraops computing. ARPA is pursuing both of these paths.

Viewgraphs 15-16:

ARPA intends to win back the high definition display technologies from our international competitors. The current state-of-the-art displays are decreasing in size and increasing in pixel density. HDS has dual use applications, and will provide high paying, high technology jobs to America's manufacturing sector.

Viewgraph 17:

ARPA's HDS program has a 3 phased approach, and is now entering phase 2. Display efforts include improved cathode ray tubes; flat panel and head-mounted displays using active matrix liquid crystals, electroluminescence, plasma, and cold cathode technologies; projection displays using digital micro-mirrors, liquid crystals, and laser projection; as well as efforts in manufacturing and enabling technologies. The program supports a consortium of display manufacturers that work in partnership with government on display industry infrastructure (e.g., manufacturing equipment, materials, standards). The program is modeled after SEMATECH. Display processor efforts include: development of high speed video processor modules, workstations, high bandwidth busses, image transmission over packet networks, and a high bandwidth, digital compressed video and data system for education and training. Various compression algorithms are being investigated including interframe compression based on the adaptive block size discrete cosine transform, MIT-CC adaptive subband video compression, and compression techniques involving fractal image coding. New graphics tools, graphics standards, and user interfaces are being developed. Research on virtual/augmented environments and scientific visualization is being conducted. New magnetic tape and recording heads for high density storage devices are being developed. An image sensor based upon acoustic charge transport devices is being developed for use in an all-digital camera. Finally, a variety of military applications will serve as demonstration vehicles for high definition system technologies.

Viewgraphs 18, 19, 20, and 21:

Some of ARPA's most promising HDS achievements include a 6 million pixel display and a digital micromirror device. The digital micromirror device is a projection technology that has over 2 million moving parts. Each mirror is supported above a silicon substrate, rotates on a torsional hinge, and can be individually addressed. It is the world's most complex microelectromechanical device, but provides high light efficiency, simple optics, and the potential for low-cost volume manufacturing

Viewgraph 22:

During the past 50 years, mechanical components have changed little in size, unlike the major size reduction experienced by their electrical counterparts. ARPA, however, is exploring fabrication materials and processes developed for the

semiconductor industry and is pursing microelectromechanical components. Key issues in MEMS technology include miniaturization, widespread use of patch processing, and merging microelectronics with mechanical systems.

Viewgraphs 23 and 24:

A notable example of MEMS' successes include inertial measurement systems. Dramatic reductions in mass, size, power, and cost have been achieved. These devices offer opportunities for beyond their traditional applications, including personal and expendable inertial guidance units.

Viewgraph 25:

Miniaturization and mass production of MEMS will lead to greater numbers of components in systems. This will result in greater system capability and greater reliability as a result of component redundancy.

Viewgraphs 26 and 27:

Another promising MEMS development is an STM sensor device equipped with an individual read/write tip and micropositioner. This device is expected to provide data storage 100,000 times the density of CD ROMs. This will dramatically change personal data storage capabilities, allowing individuals to carry a library of information on their person./

Viewgraph 28:

To reduce the barriers to entry into MEMS, ARPA is funding a foundry at MCNC in North Carolina. This program allows designers to submit a MEMS design for fabrication on a wafer at a cost of only $500. This program provides low-cost, low-volume access to MEMS fabrications facilities, encouraging universities and corporations to exploit the technology.

Viewgraph 29:

MEMS technology will cause a revolution in the perception and control environment by increasing the capability, affordability and number of smart systems. The long-term goal of MEMS is to network computation, sensors and actuators, and mechanical structure to change the way people and machines interact with the physical world, leading to revolutionary new system capabilities.

Viewgraphs 30, 31 and 32:

ARPA is pursuing Tactical Display Systems, which provide small (1 square inch) high-resolution displays that can be inserted in current military equipment. One such piece of hardware is a MELIOS laser range finder, modified with a GPS, a mass data storage medium, a computational device, and a CCD. Inserting these capabilities greatly enhances the value of the hardware, improving battlefield intelligence collection, targeting, and situational awareness.

Viewgraph 33:

Low-bandwidth distributed sensors will revolutionize military operations, maintenance, and logistics. For example, by distributing these sensors on a soldier's equipment and providing a wireless tether, the readiness status of key items can be determined in real-time. This eliminates time consuming inventories which are frequently performed during combat operations.

Viewgraph 34:

The final ESTO program for discussion is Biomedical Sensors and Analytical Instruments. The primary goal of this program is to develop unobtrusive, noninvasive biomedical sensors that can be used to provide the real-time readiness status of individual military personnel. This program has widespread dual-use applications in the health care industry where it can permit remote (home) monitoring of patients, reducing the cost of care. Several issues that are being addressed by the program are noninvasiveness, miniaturization, stability, reliability, power consumption, and environmental ruggedness.

Viewgraph 35:

In summary, Electronics at ARPA are principally focused on three principle electronic areas: Microelectronics; Electronic Modules and Systems; and Sources, Sensors, Actuators, and Displays. It is a dynamic environment encompassing a broad spectrum of programs. As an ARPA supplier, you are encouraged to bring us your great ideas.

Electronics at ARPA

Microelectronics Technology Office
Electronic Systems Technology Office

Microelectronics
- Microelectronics Manufacturing—SEMATECH, MMST, Lithography
- Semiconductor Process Synthesis
- Optoelectronics for Information Processing
- Ultra-dense ultra-fast computing components
- HBT A/D converter technology

Electronic Modules and Systems
- Electronic Packaging and Interconnect
- Embedded Microsystems
- Signal processing—RASSP

Sources, Sensors, Actuators, and Displays
- Microwave and mm-wave integrated circuits—MIMIC
- High Definition Systems
- Infrared Focal Plane Arrays
- Microelectromechanical Systems

Electronic Systems Technology for Smaller, Thinner, More Mobile Information Systems

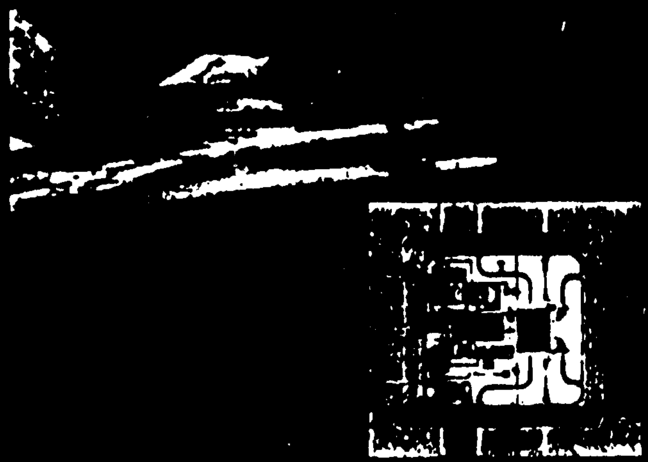
- Sensors, sources, actuators, and displays
- Signal processing where the signals are
- Manufacturing and precision assembly
- Electronic packaging and interconnect
- Low-energy computing and wireless communication

ESTO Technologies

- *MIMIC* program on microwave and mm-wave integrated circuits. Critical front end components for Radars, Smart Weapons, Communications, and EW.
- *High-Definition Systems,* including high-definition display technology and head-mounted systems. From data and computation to human understanding in time-constrained situations.
- *Application-Specific Electronic Modules (ASEM).* Information technology for the rapid and affordable development and manufacturing of electronic modules and subsystems.
- *Physical packaging.* Technology for electronic packaging including multi-chip and 3-D modules. Mixed signal modules.
- *Rapid Prototyping of Application Specific Signal Processors (RASSP).* Demonstrate a capability to rapidly specify, produce, and field domain-specific affordable signals processors for use in DoD systems
- *Embedded Microsystems.* Technology for low-energy signal processing.
- *Micro Electro Mechanical Systems.* Microsensors and actuators. Conformal Electronics. Adaptive wireless communication systems. Biomedical Electronics. *Other...*

PRODUCTION SYSTEMS WITH MIMICs INSERTED USED IN DESERT STORM

HARM



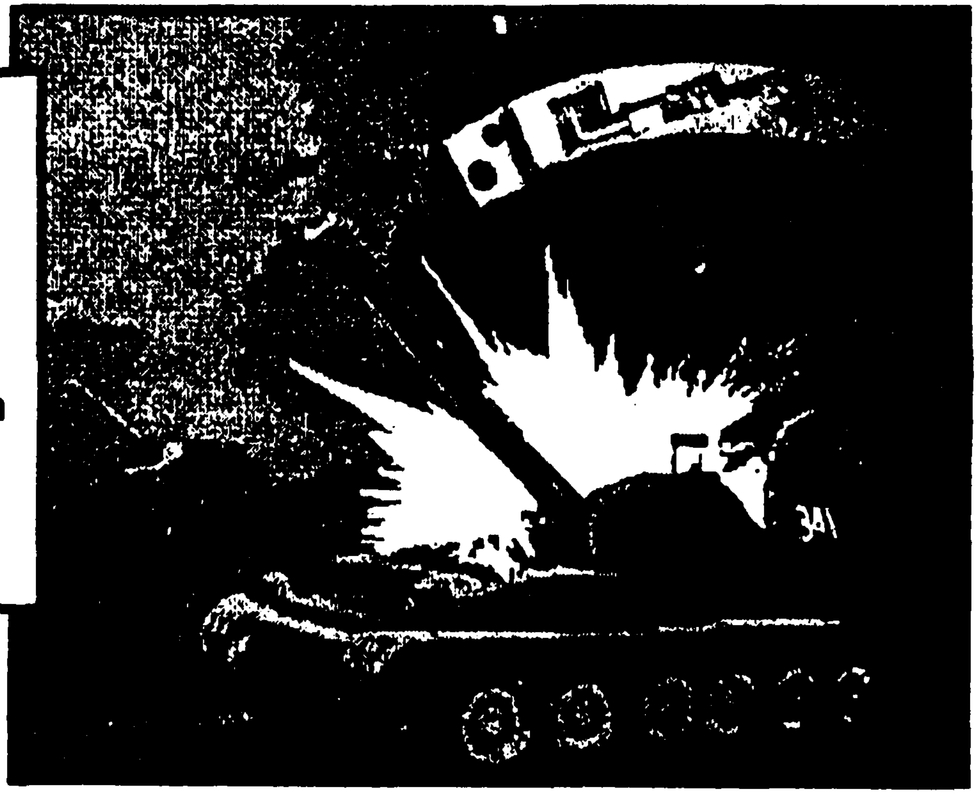
LANTIRN

- HARM Played Key Defense Suppression Role
- First MIMIC Insertion In IF Receiver Completed In 1989
- Second Insertion In Microwave Receiver Being Qualified In 1991
- MIMICs Provide Cost Effective Solution to Tough Performance Requirements

- LANTIRN Guided F—15s / F—16s to Targets In Night Attacks
- Wideband MMIC Amplifier Used In Receiver/Exciter LRU
- MIMIC Implementation Provided Complex Function Realization In Highly Constrained Volume

MIMIC
SEARCH AND DESTROY ARMOR (SADARM)

- Key challenges met
  - ▶ Two chip macrocell transceiver
  - ▶ Cost/size reduction
    - 10:1 volume reduction
    - $350 per unit cost reduction
    - 2:1 reliablility improvement
  - ▶ 3 dB noise figure improvement



"There are no substitutes for the MIMIC technology used on SADARM",
U.S. Army Research, Development and Engineering Center

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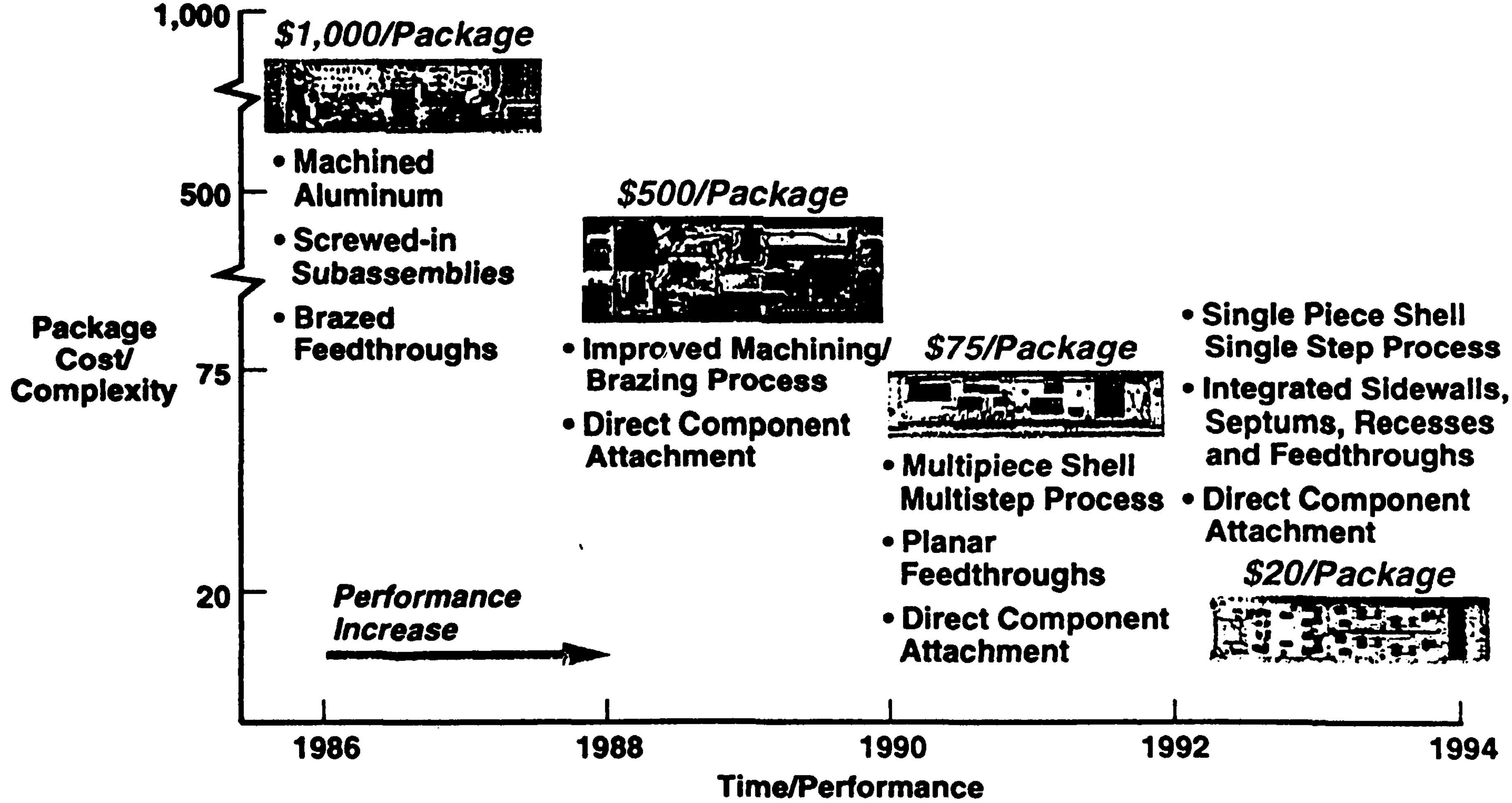
MIMIC PACKAGE TECHNOLOGY EVOLUTION



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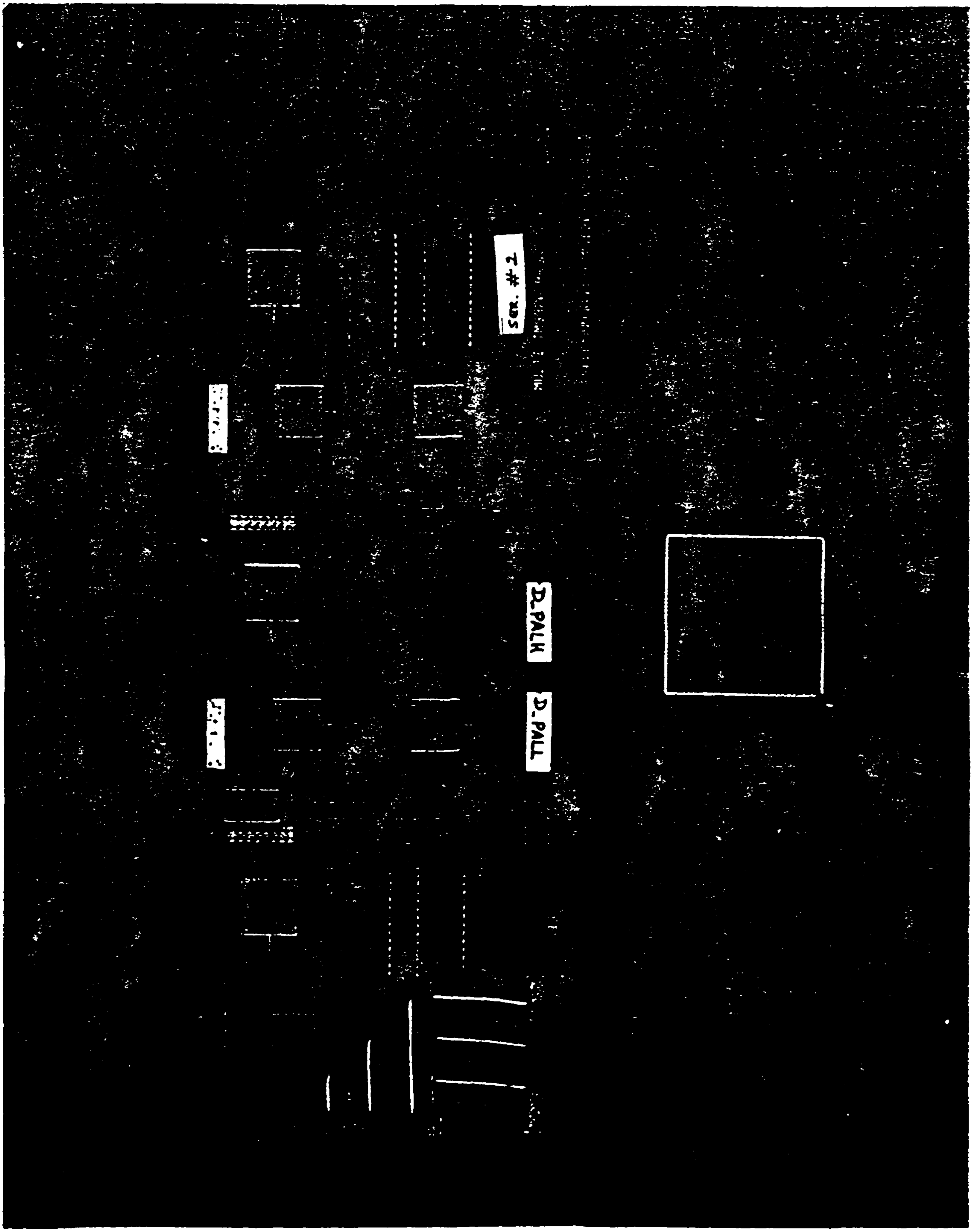
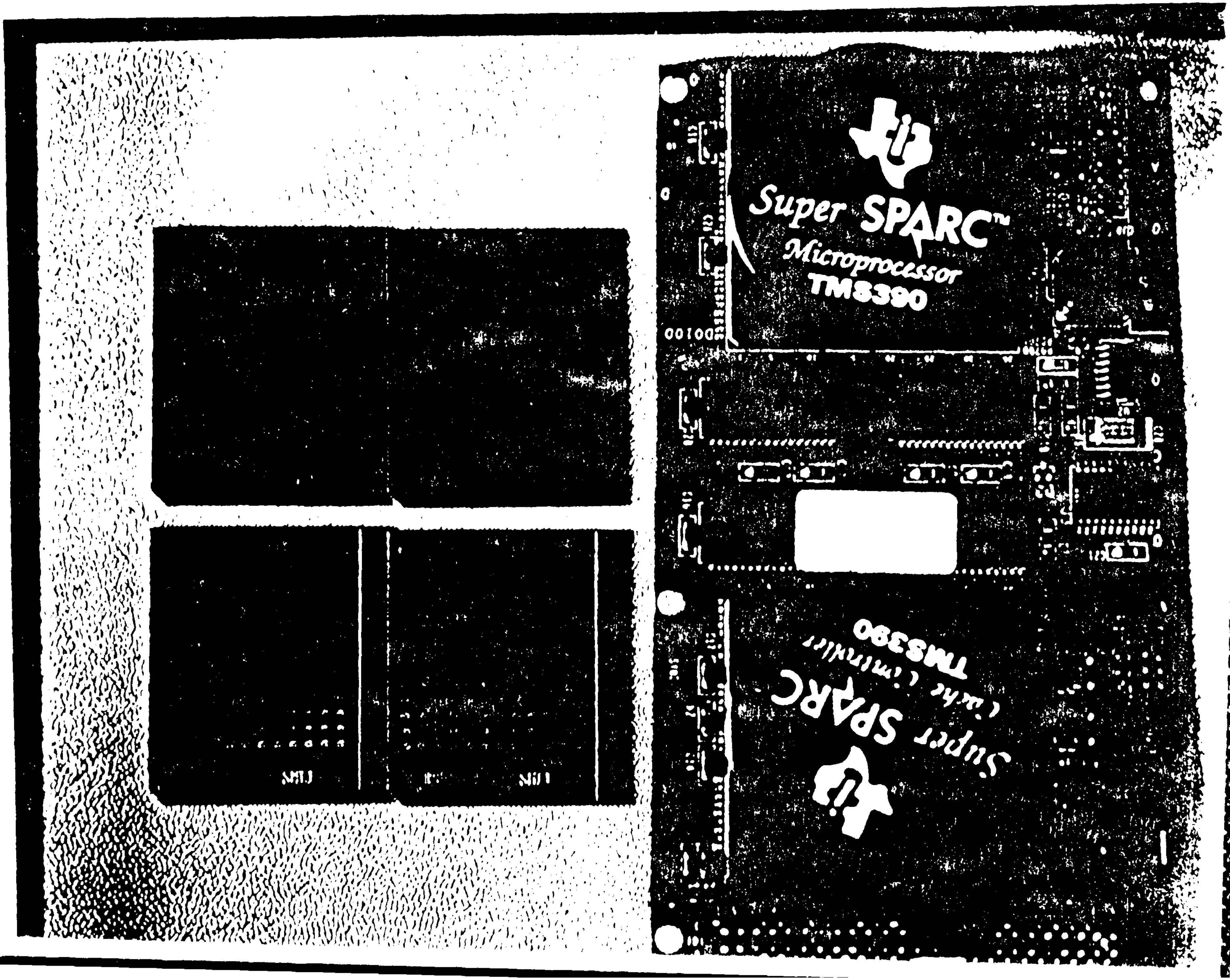
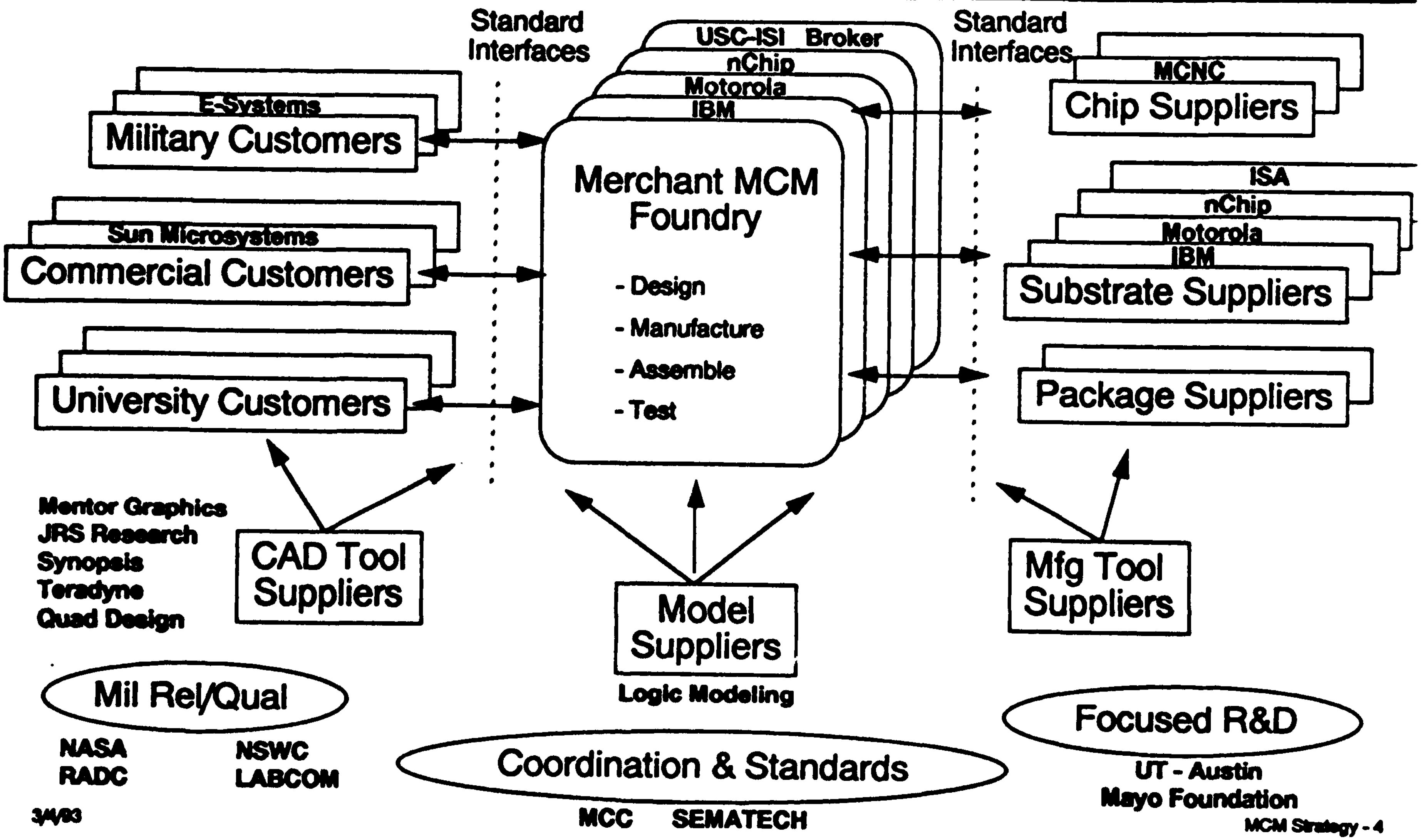


SER. #2
D.PALH
D.PALL


Super SPARC™
Microprocessor
TMS390
Super SPARC
TMS390

ASEM Program Structure



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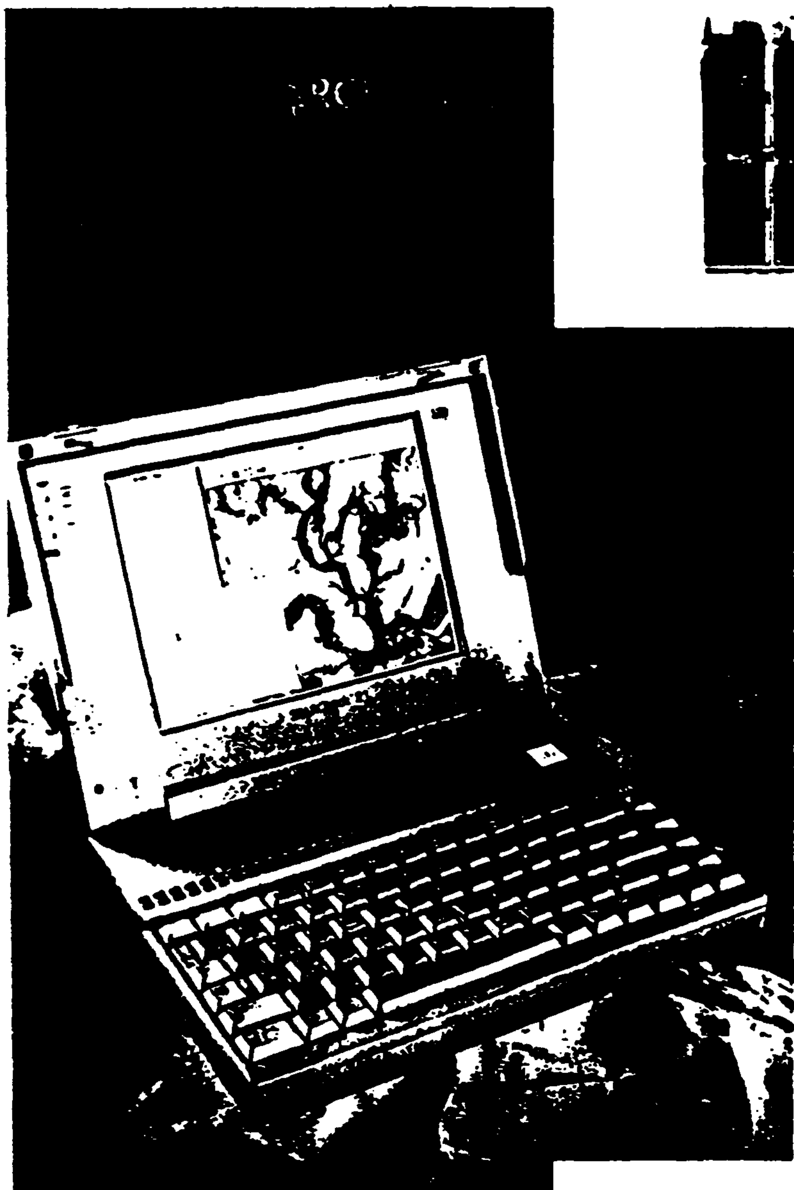
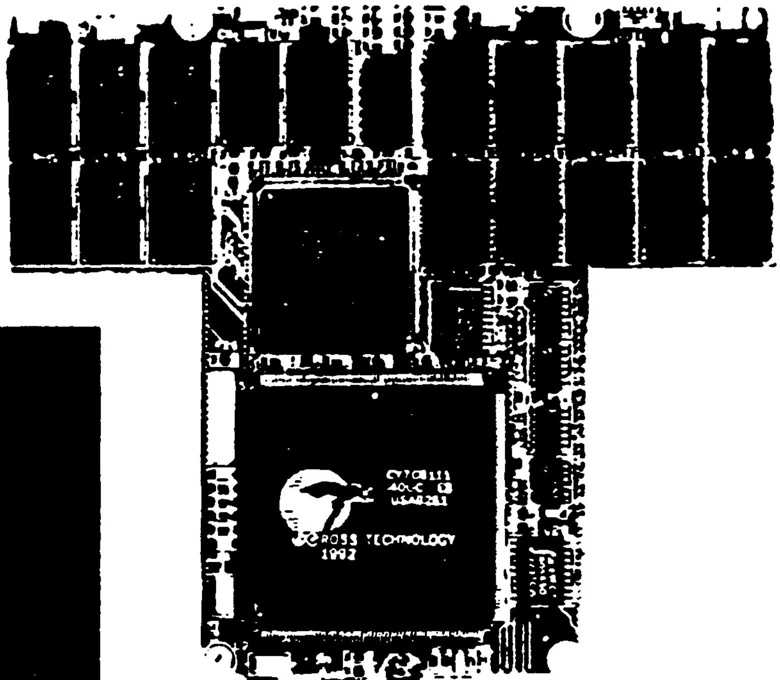
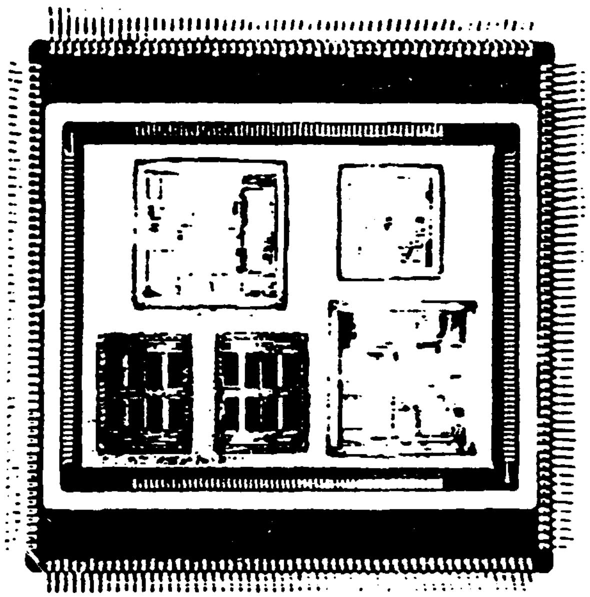






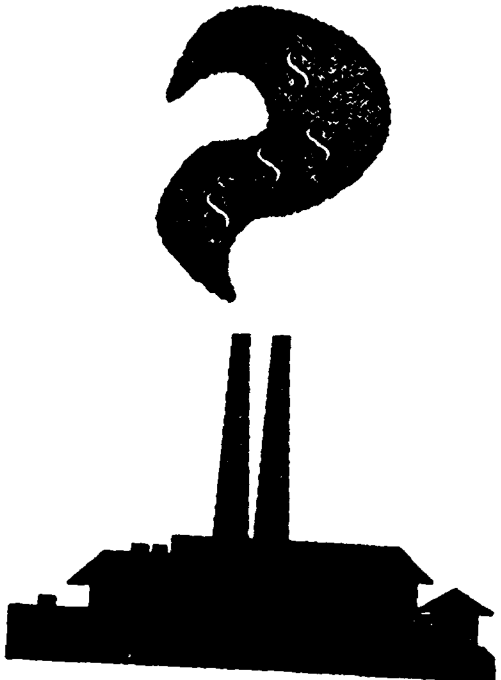
Specifications

Processor	40MHz SPARC CY6111 nCHIP module including 40MHz CY601 Integer Unit, CY602 FPU and CY604 Cache MMU with 64KB direct mapped virtual cache, zero wait state
System Performance	28 MIPS, 4.4 MFLOPS, SPECint92 19.6, SPECfp92 21.2
Memory	16, 32 or 64MB DRAM with byte parity protection
Internal Display	9.4" side-lit color active matrix TFT LCD displays 640 x 480 resolution and 256 colors from a palette of 512/4096
External Display	Supports external monitors and projectors with software selectable 640 x 480, 1024 x [illegible] and 1152 x 900 resolution and displays 256 colors from a palette of 16.7 million VGA 15-pin D-type interface; Sun monitor cable adapter included
Storage	250MB or 500MB 2.5" internal SCSI hard drive storage, 12 mS average access time

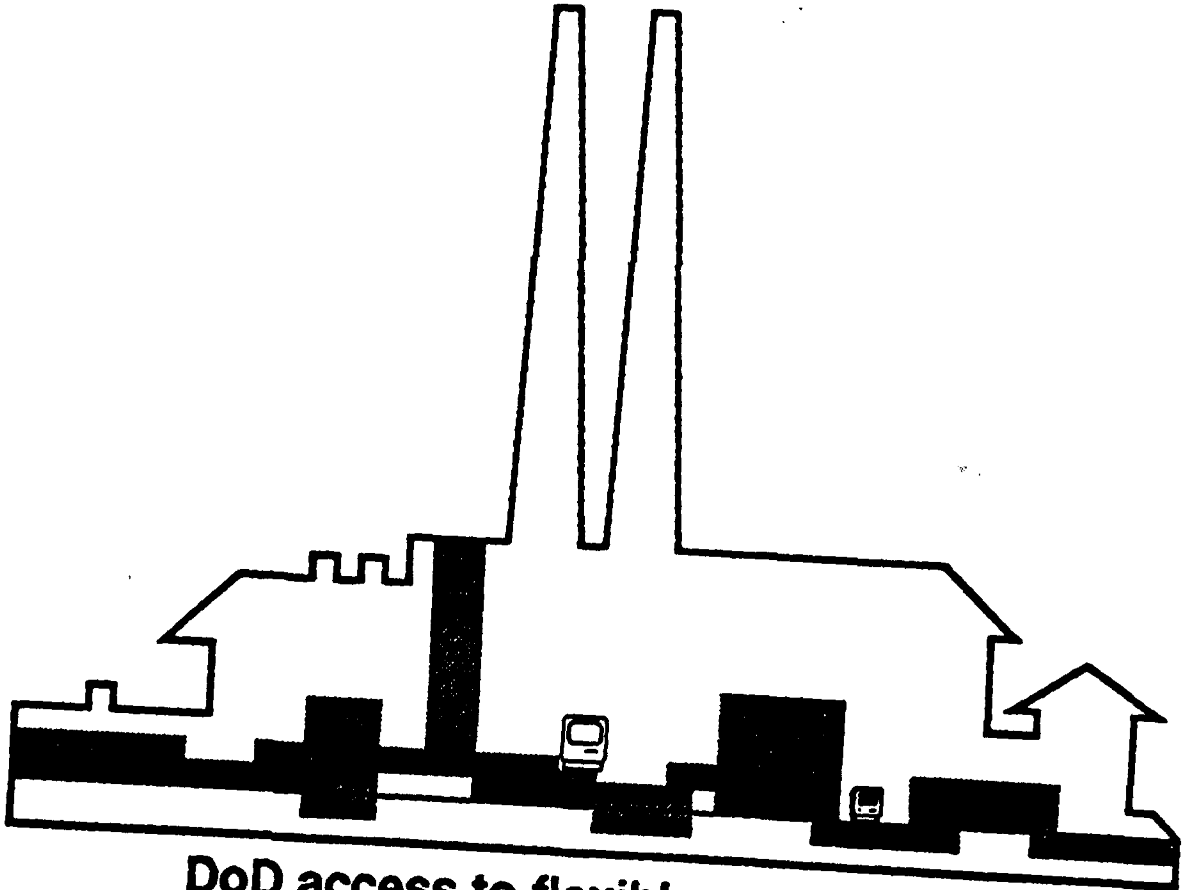
ROSS

nCHIP

Manufacturing

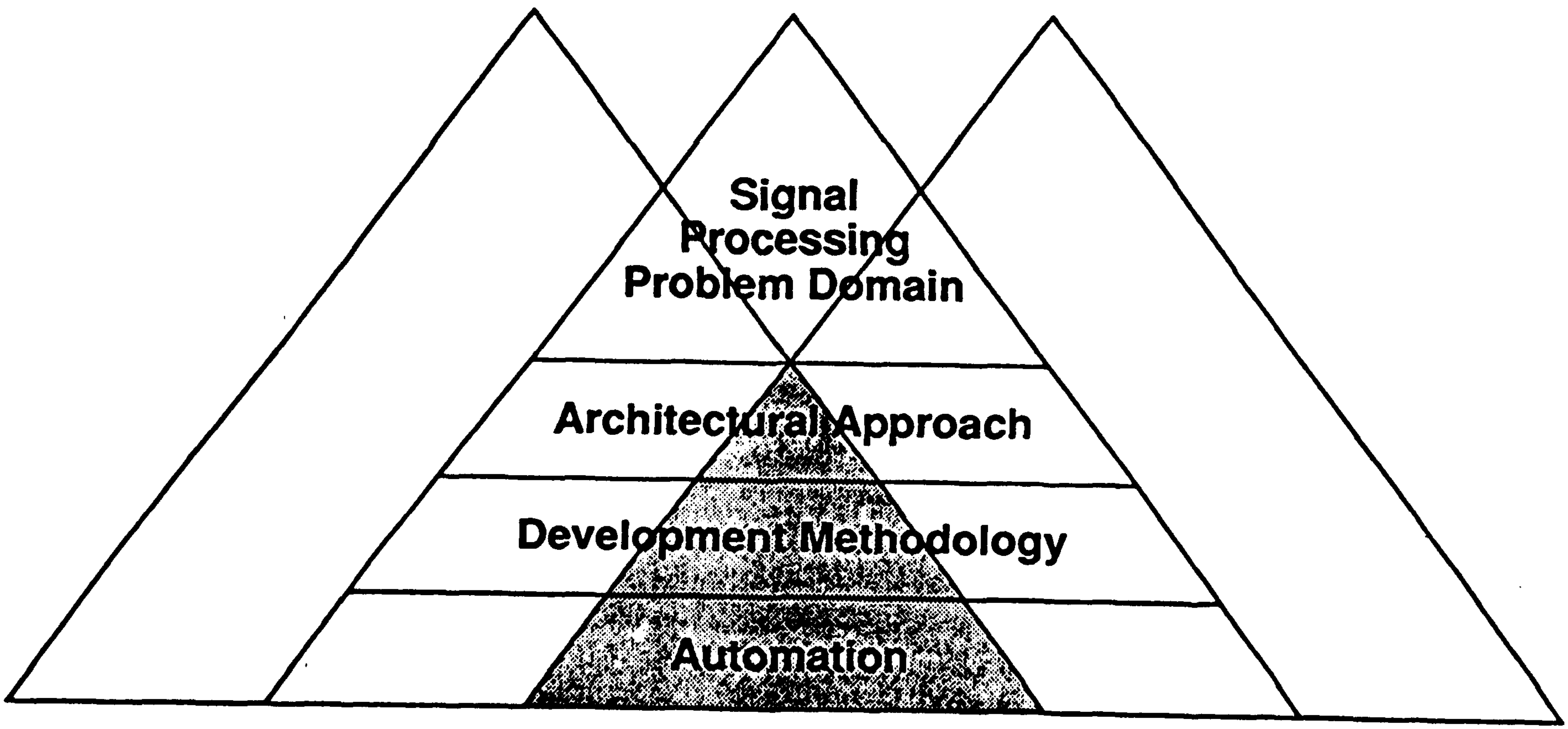


DoD unique

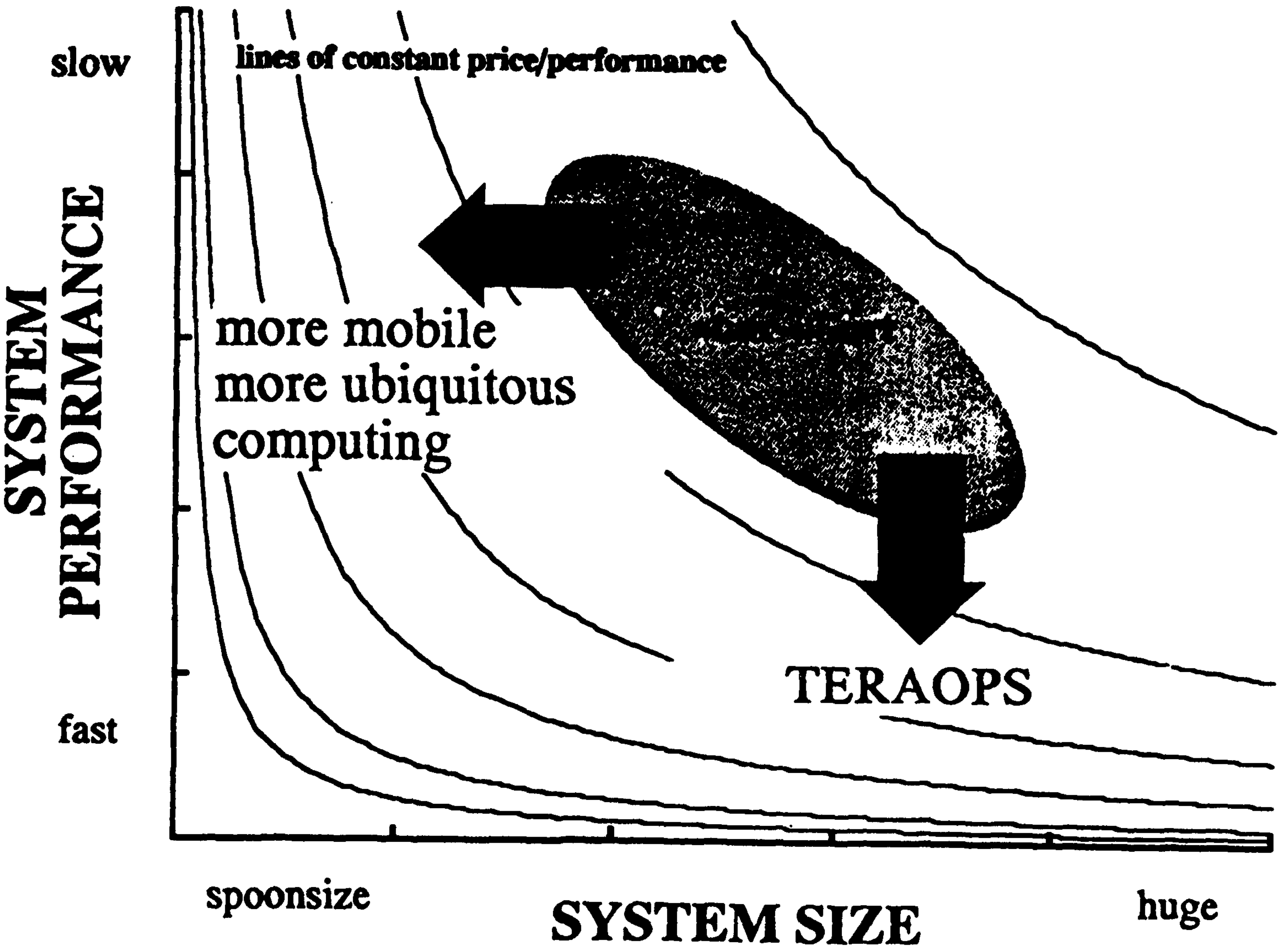


DoD access to flexible commercial

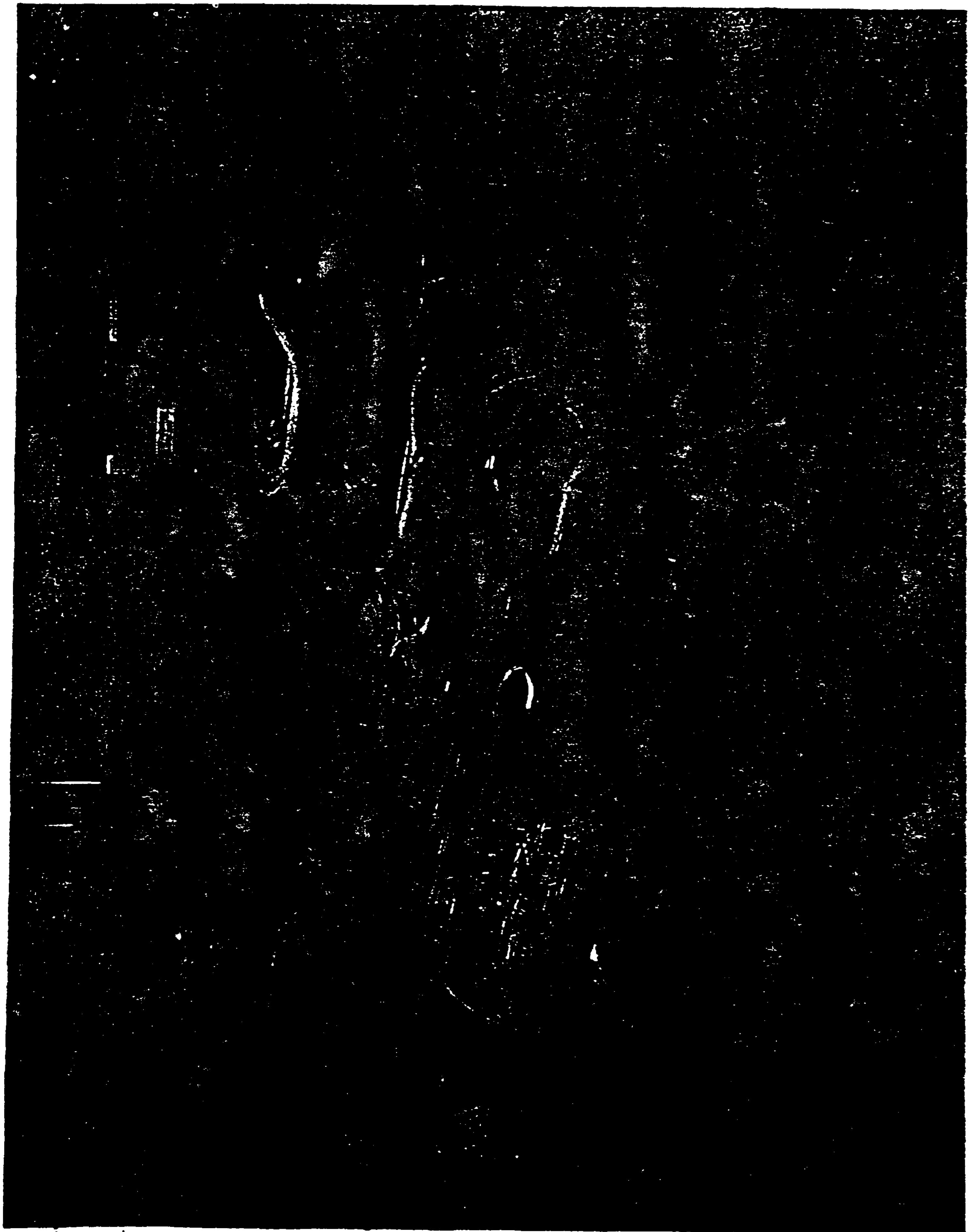
ELECTRONIC SYSTEM SUPPORT



Information Technology on the Move



4/21/92



SHARP®

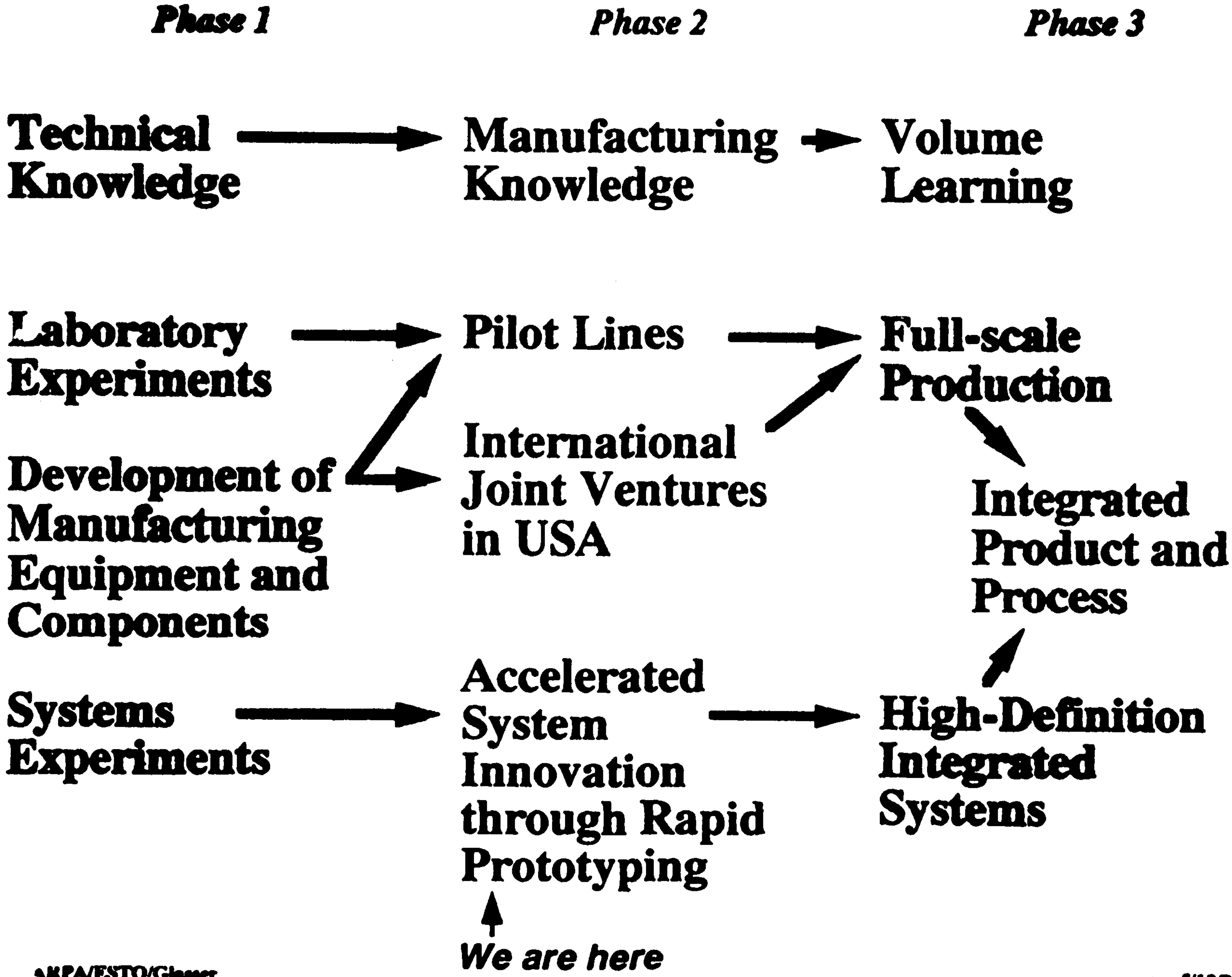
液晶ビューカム

VL-HL1 Hi8

液晶ビデオカメラ

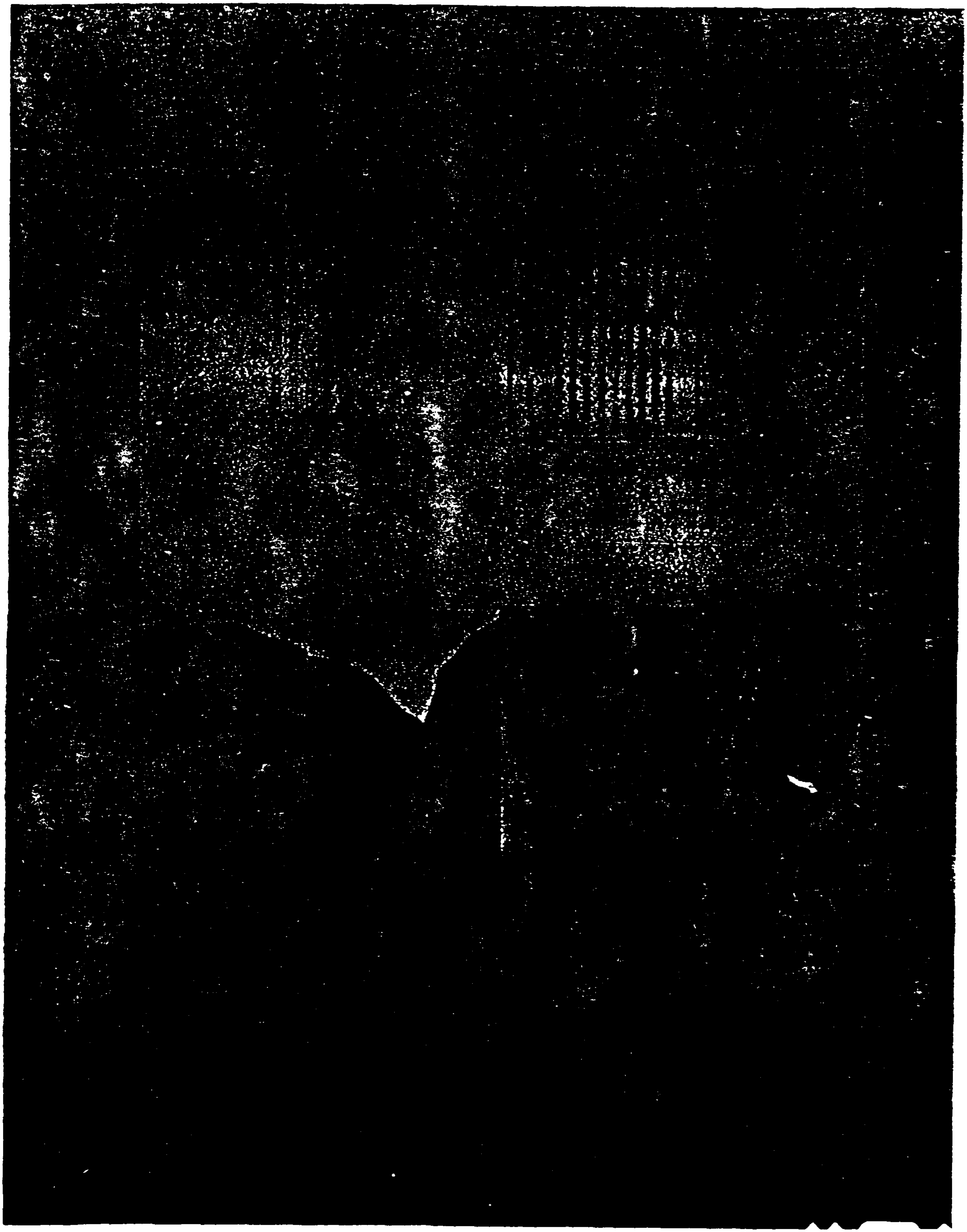
シャープ株式会社

Roadmap

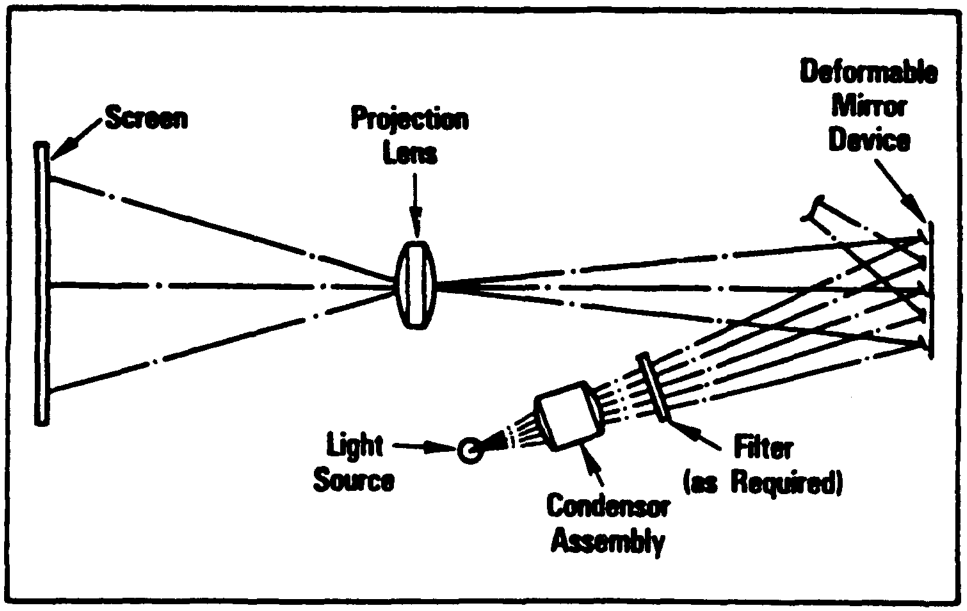


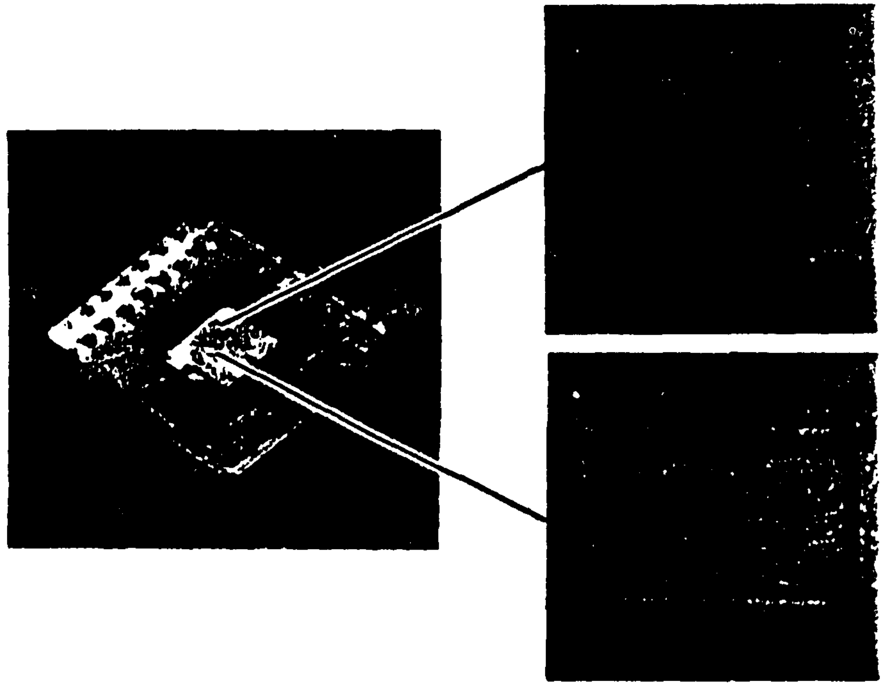
ARPA/ESTO/Glasser

rev 5/18/93



DEFORMABLE MIRROR DEVICE (DMD) PROJECTOR
TEXAS INSTRUMENTS – DALLAS, TEXAS



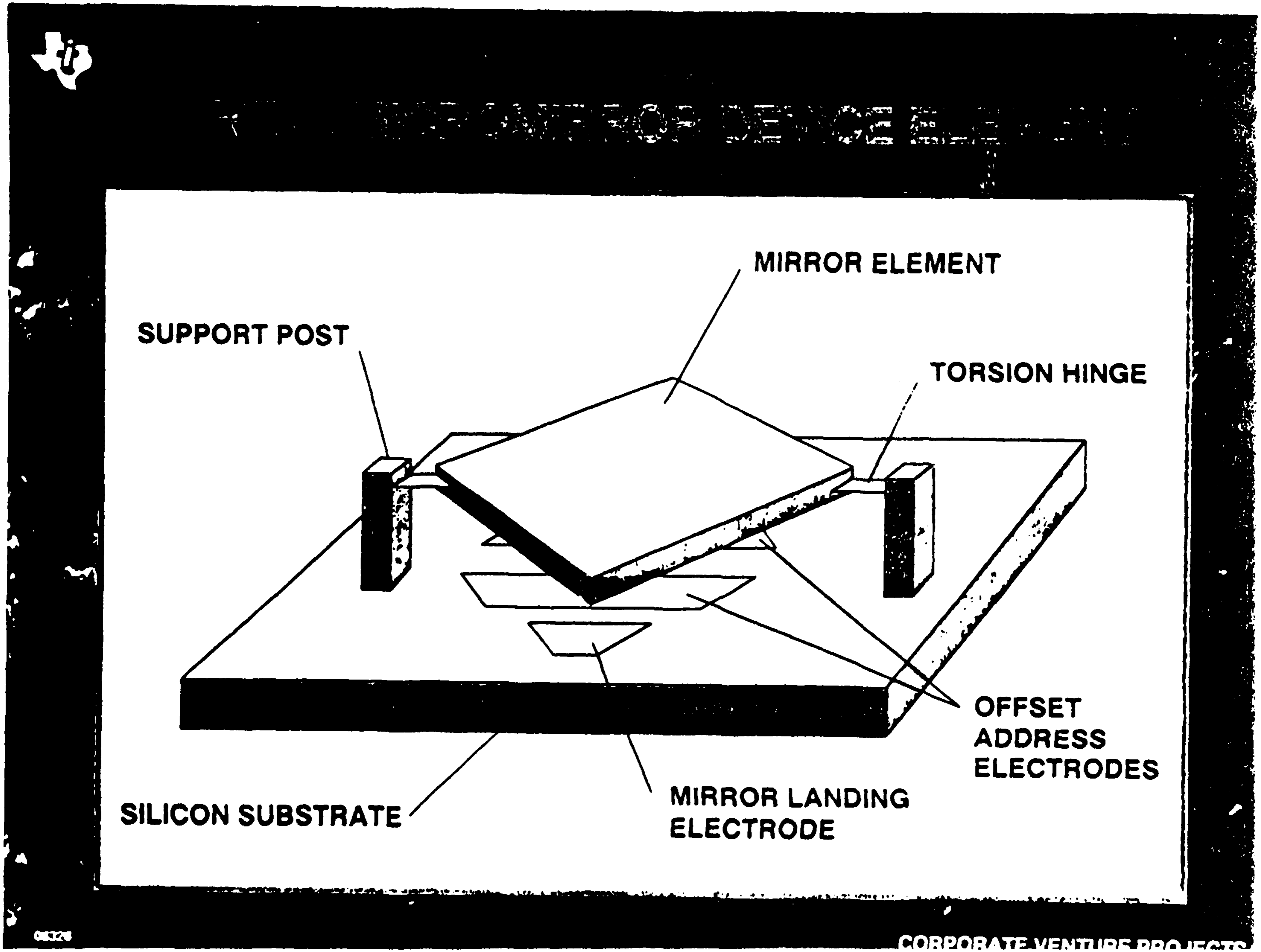


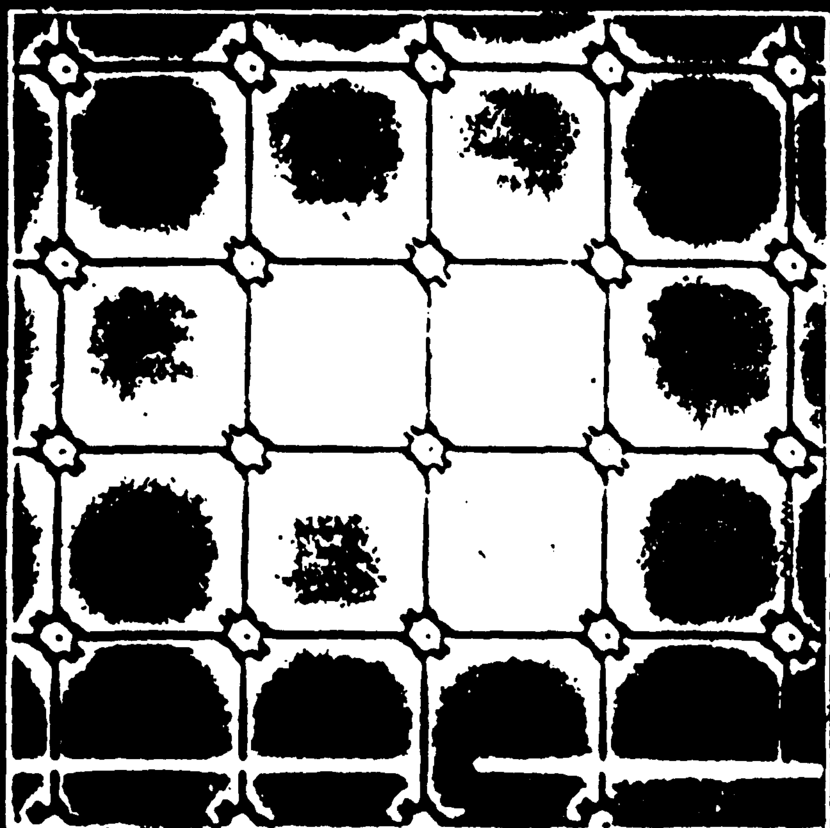
Challenge

- World's most complex micromechanical device
- Over 2,000,000 moving parts
- Over 2,000,000 transistors

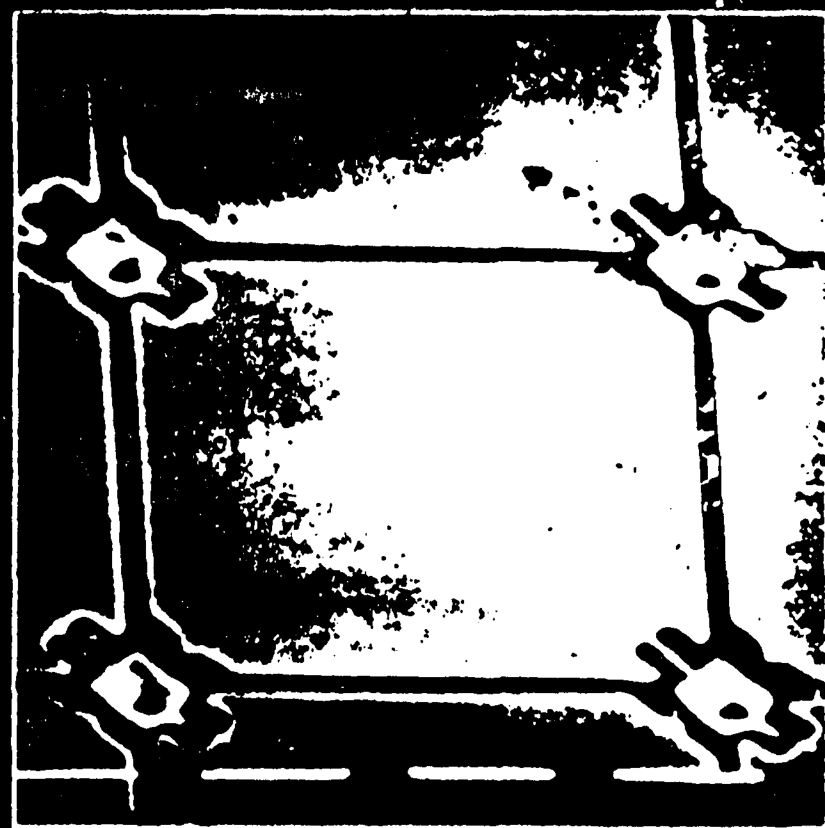
Payoffs

- High light efficiency
- Simple optics
- Low-cost volume manufacturing possible


MIRROR ELEMENT
SUPPORT POST
TORSION HINGE
OFFSET
ADDRESS
ELECTRODES
MIRROR LANDING
ELECTRODE
SILICON SUBSTRATE
CORPORATE VENTURE PROJECTS



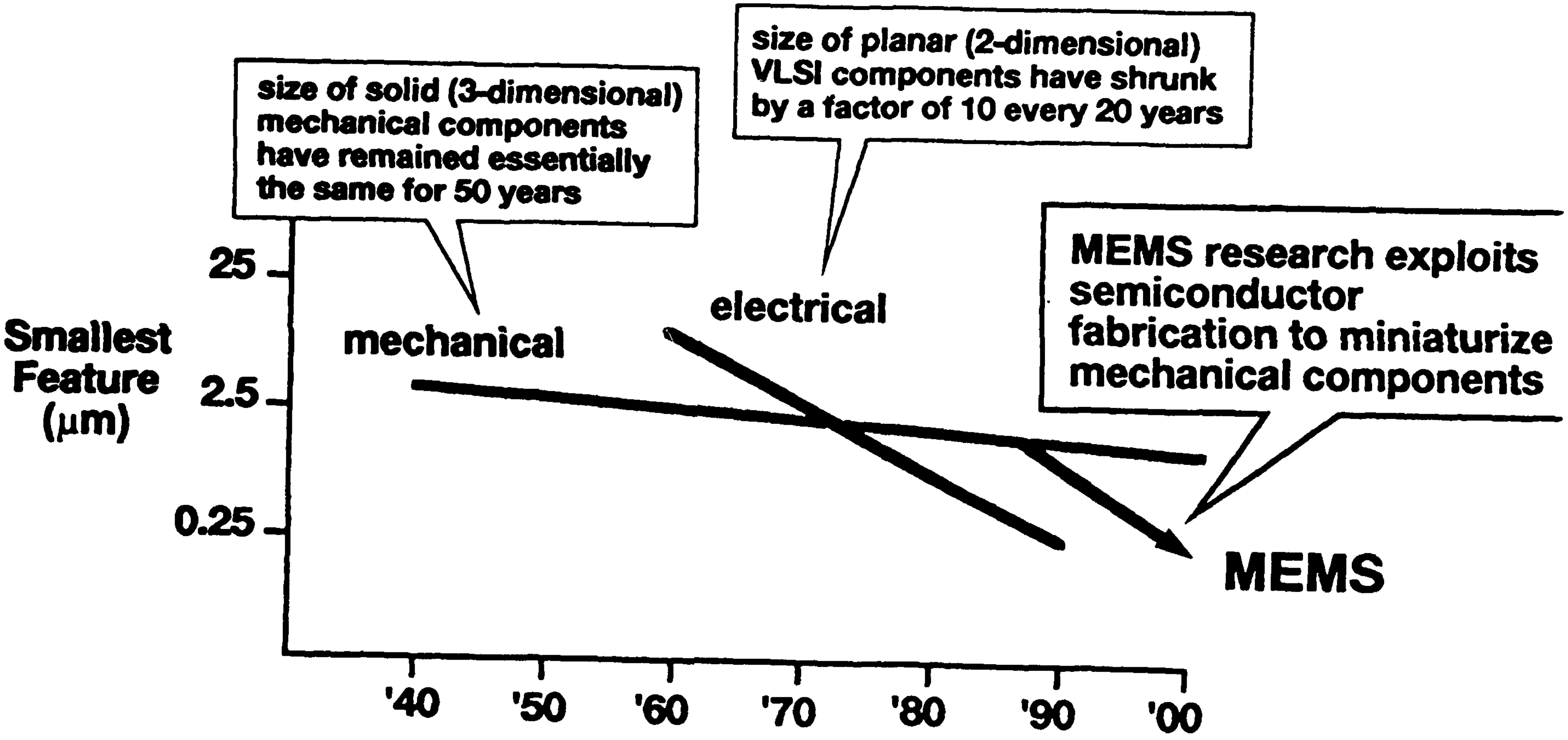
Portion of Area Array



Close-Up of Single Pixel

08313

Miniaturization of Mechanical and Electrical Components

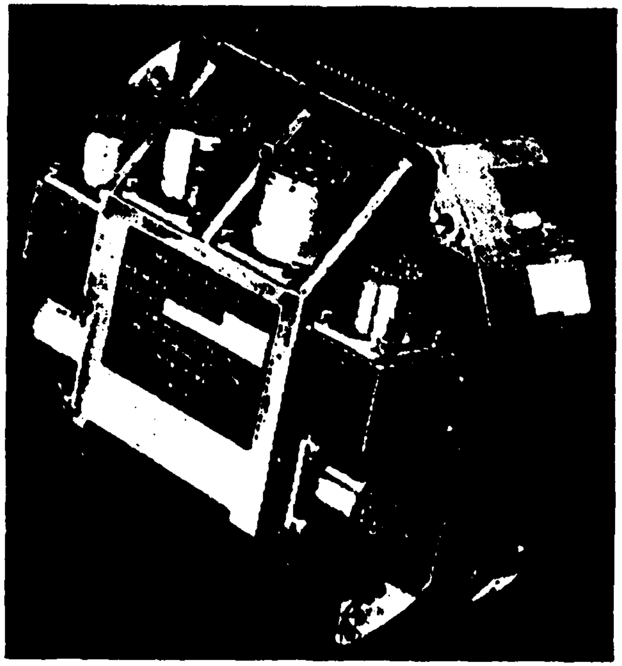


ESTO/Gabriel

rev 8/7/92

MICROELECTROMECHANICAL SYSTEMS (MEMS)
INERTIAL MEASUREMENT SYSTEMS

BEFORE

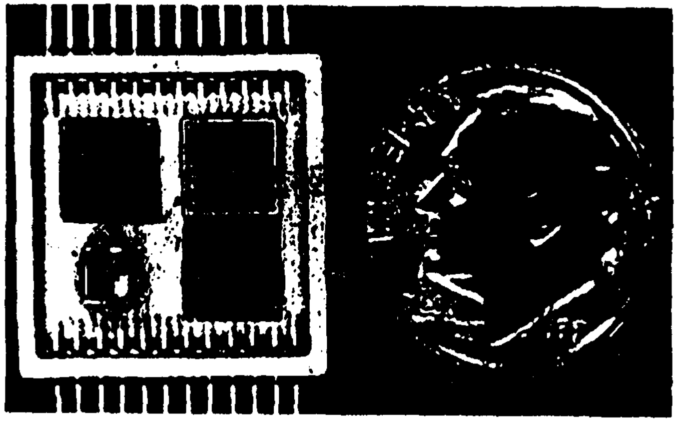


Mass: 1587.5 grams
Size: 15 x 8 x 5 cm
Power: 35 W
Survivability: 35 g's
Cost: $20,000

ESTO →

AFTER

Inertial Measurement Unit

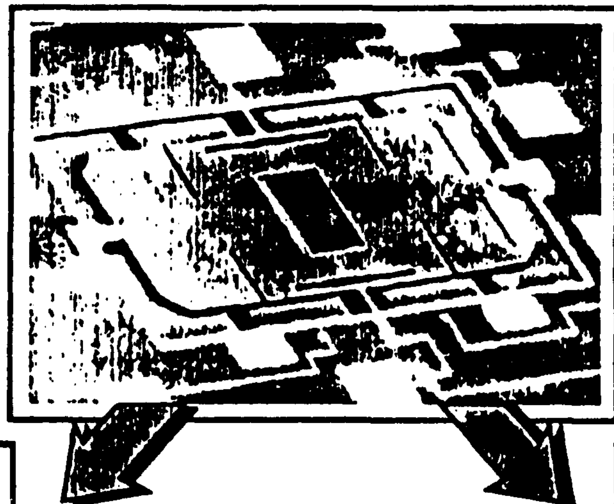


Mass: 10 grams
Size: 2 x 2 x 0.5 cm
Power: ~ 1 mW
Survivability: 100K g's
Cost: $500

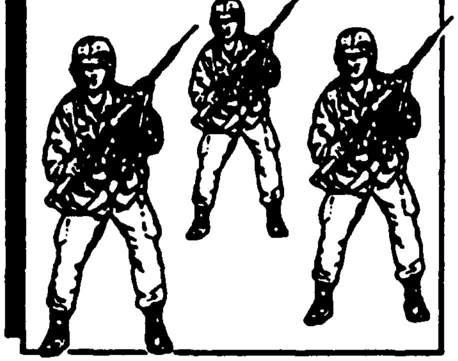
1836-10-22-92-9
R12-7-92

MICROSENSORS AND ACTUATORS

High Dynamic
Range µG-Resolution
Accelerometers

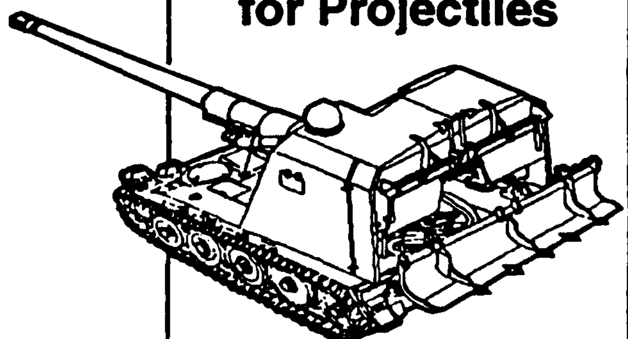


Personal Inertial Guidance Units



Augment GPS, Enable Group Connectivity and Communication

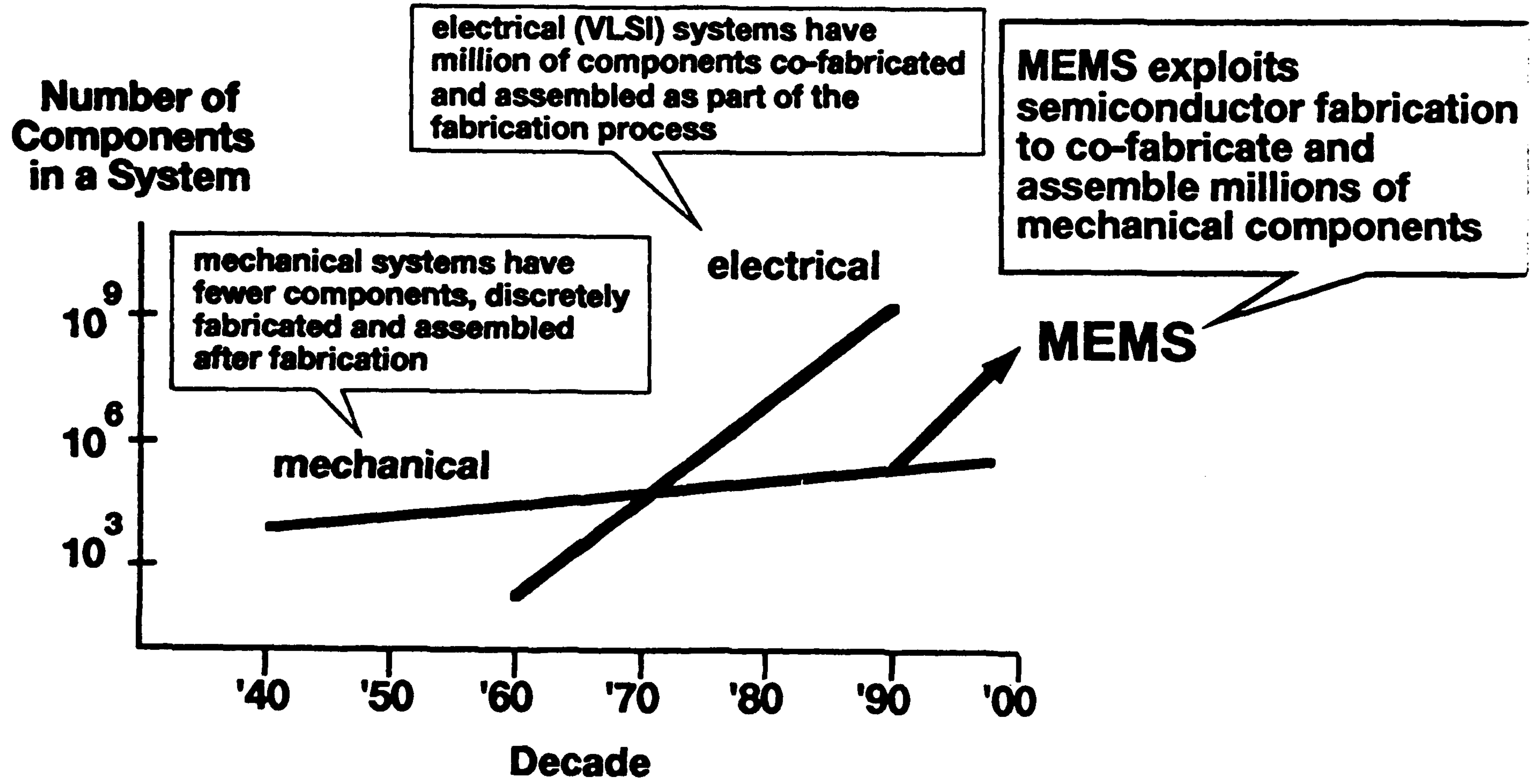
Expendable Inertial Guidance Units for Projectiles



Increased Delivery Accuracy

1838-10-22-92-7

Fabrication of Mechanical and Electrical Systems



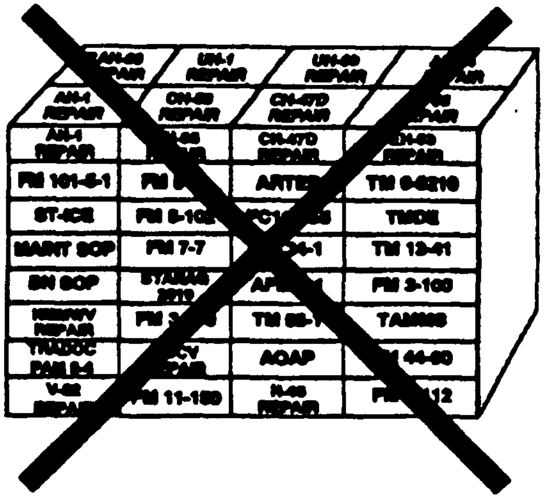
ESTO/Gabriel

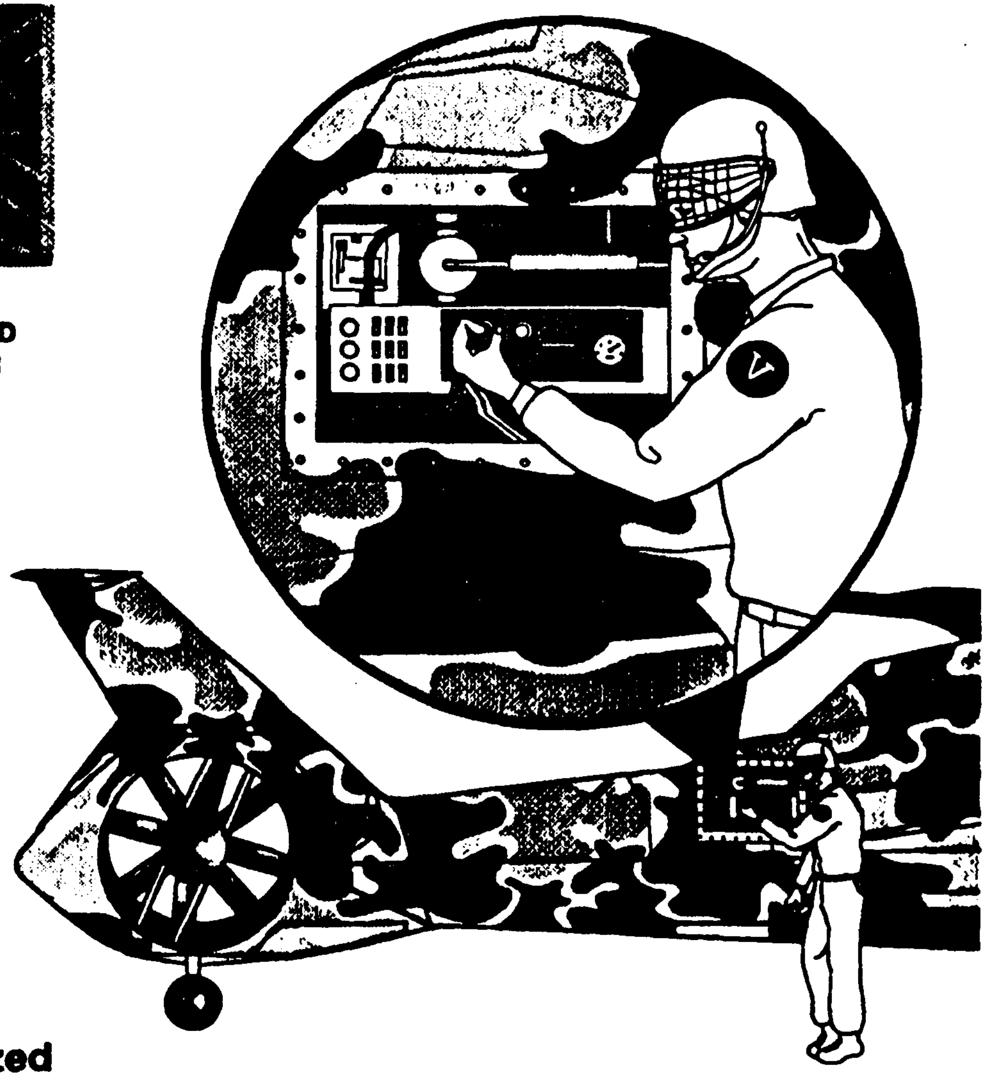
rev 8/7/92

MASS DATA STORAGE

- Portable, personal data storage 100,000 times the density of CD ROMs

INDIVIDUAL
READ/WRITE TIP AND
MICROPOSITIONER

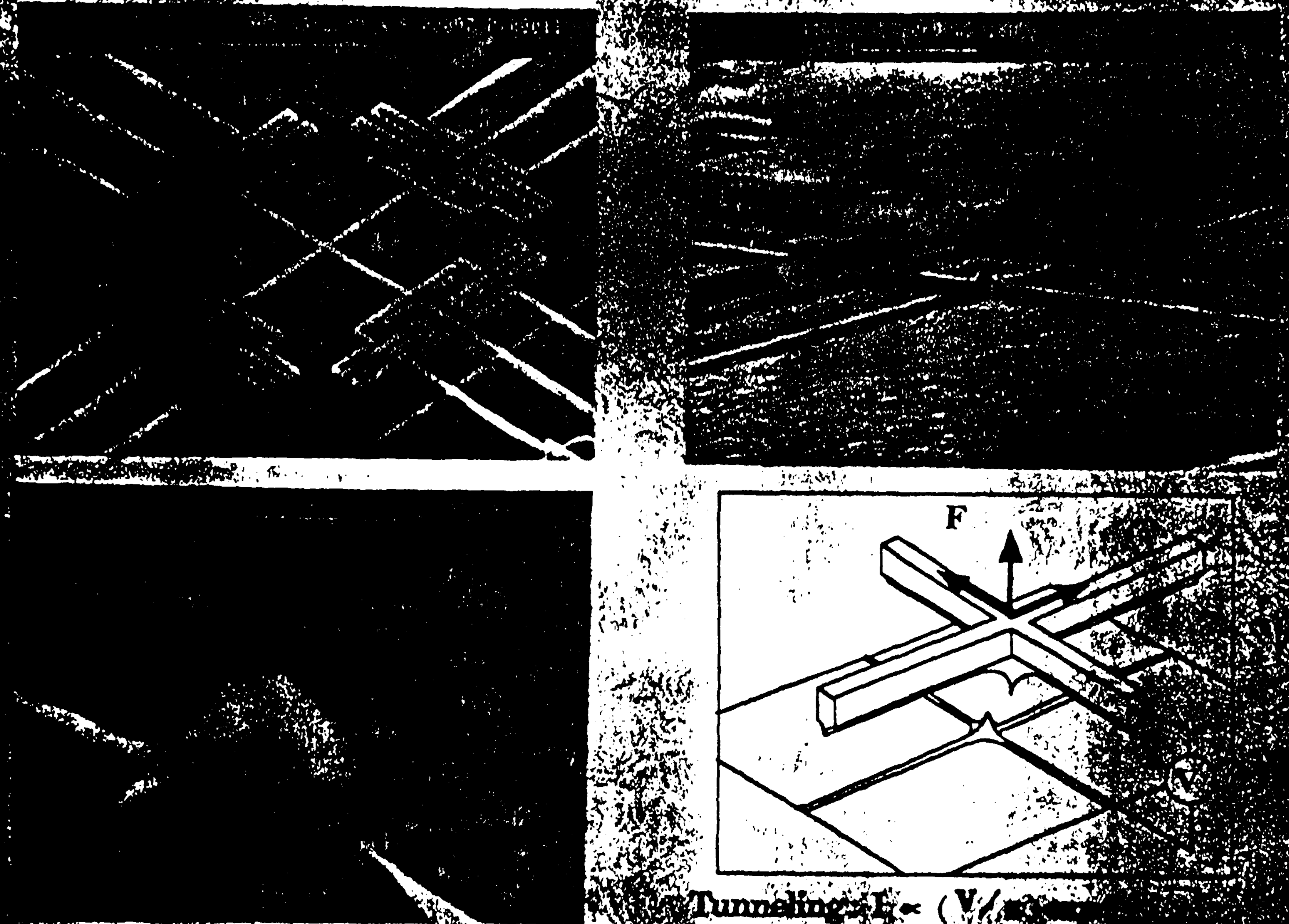




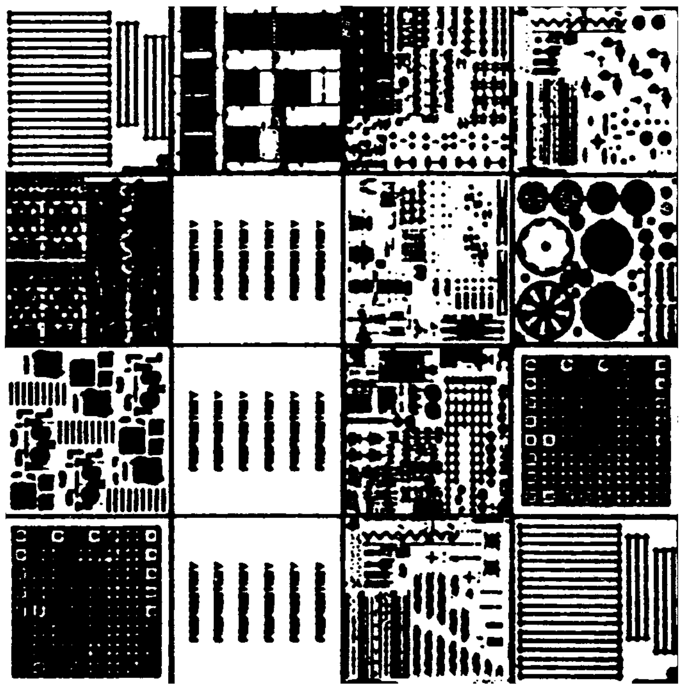
- One service member
  - Can carry *all* of the maps ever digitized
  - Can carry a *library* of SOPs, technical, and field manuals for operations, maintenance and training requirements

1838-2-18-93-1

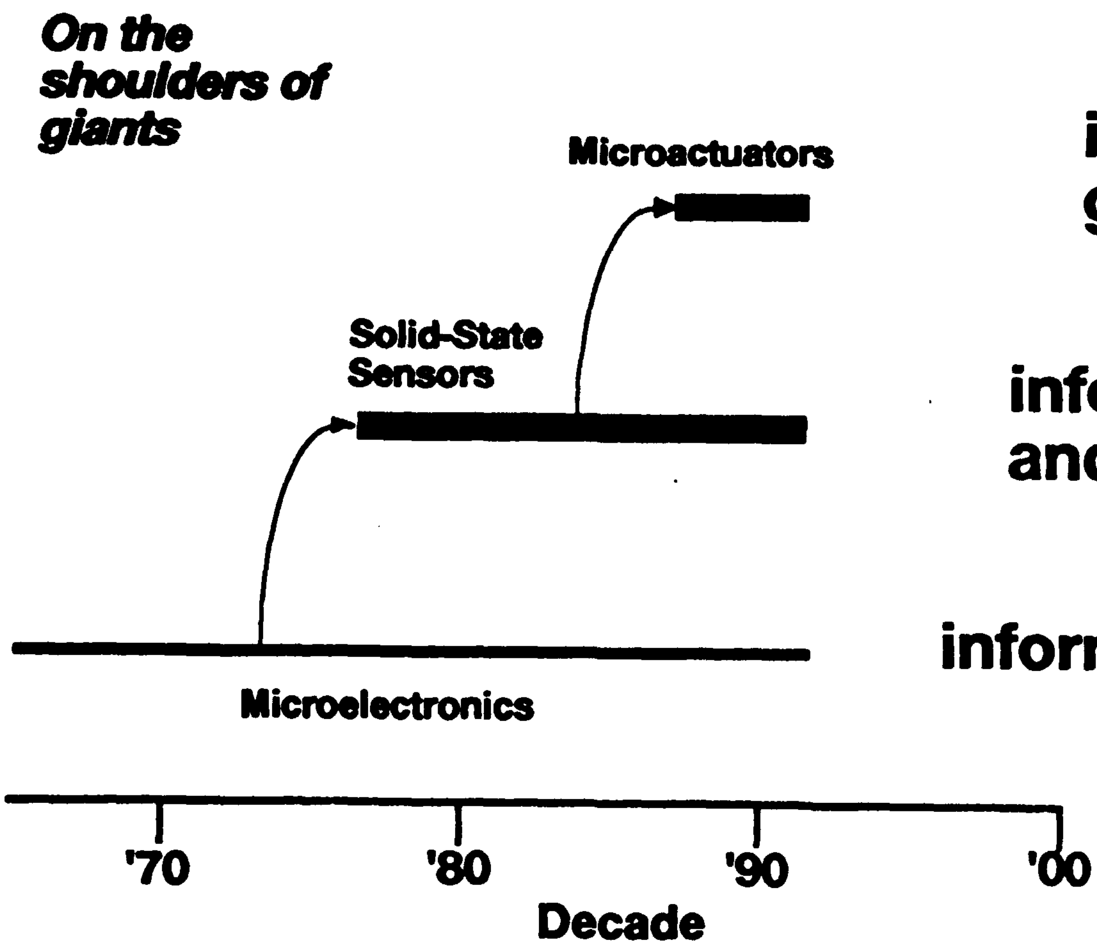
STM SENSOR DEVICE



Tunneling: I ∝ (V/



MEMS Increases the Capability, Affordability & Number of Smart Systems



information processing, gathering and <u>control</u>

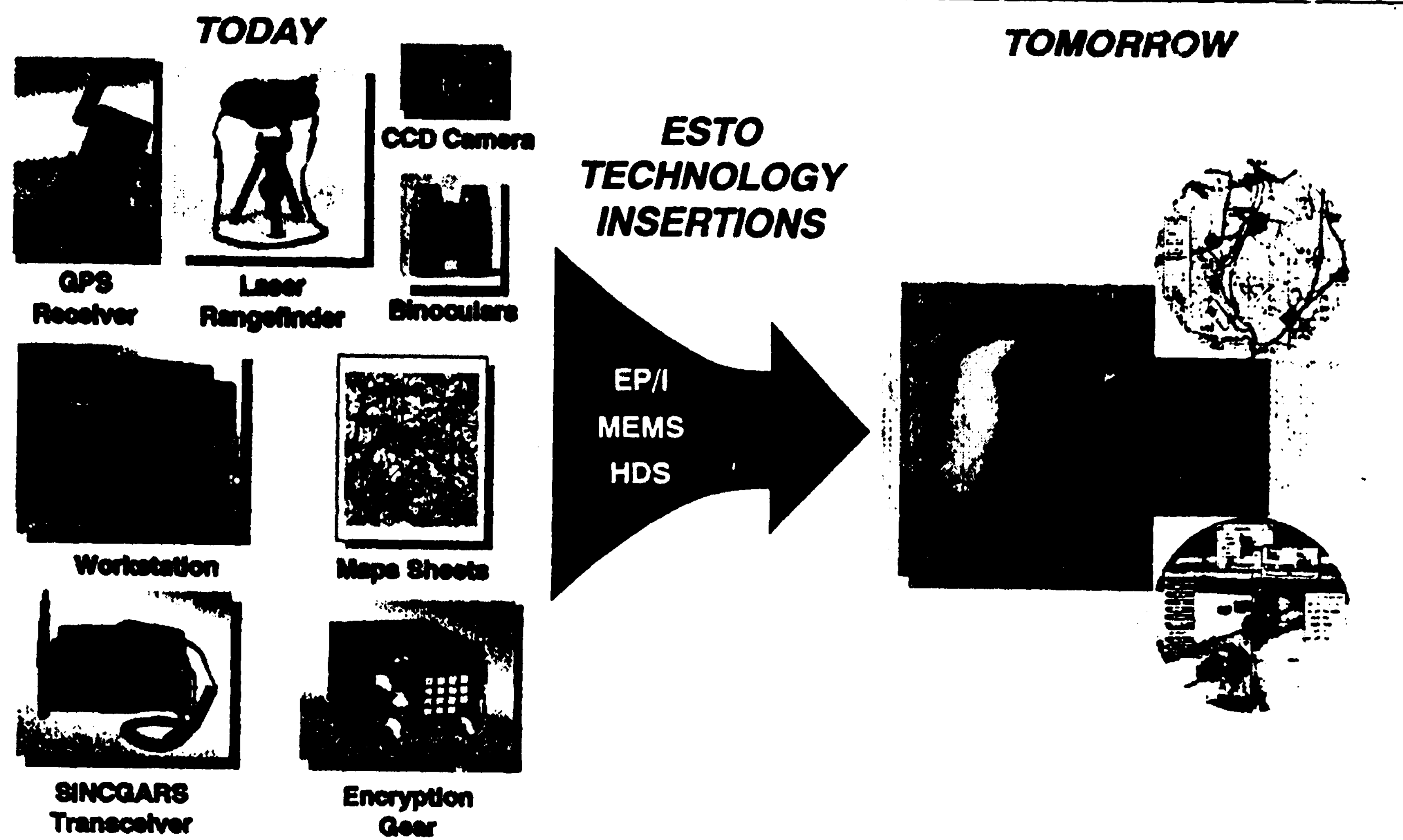
information processing and <u>gathering</u>

information <u>processing</u>

ESTO/Gabriel

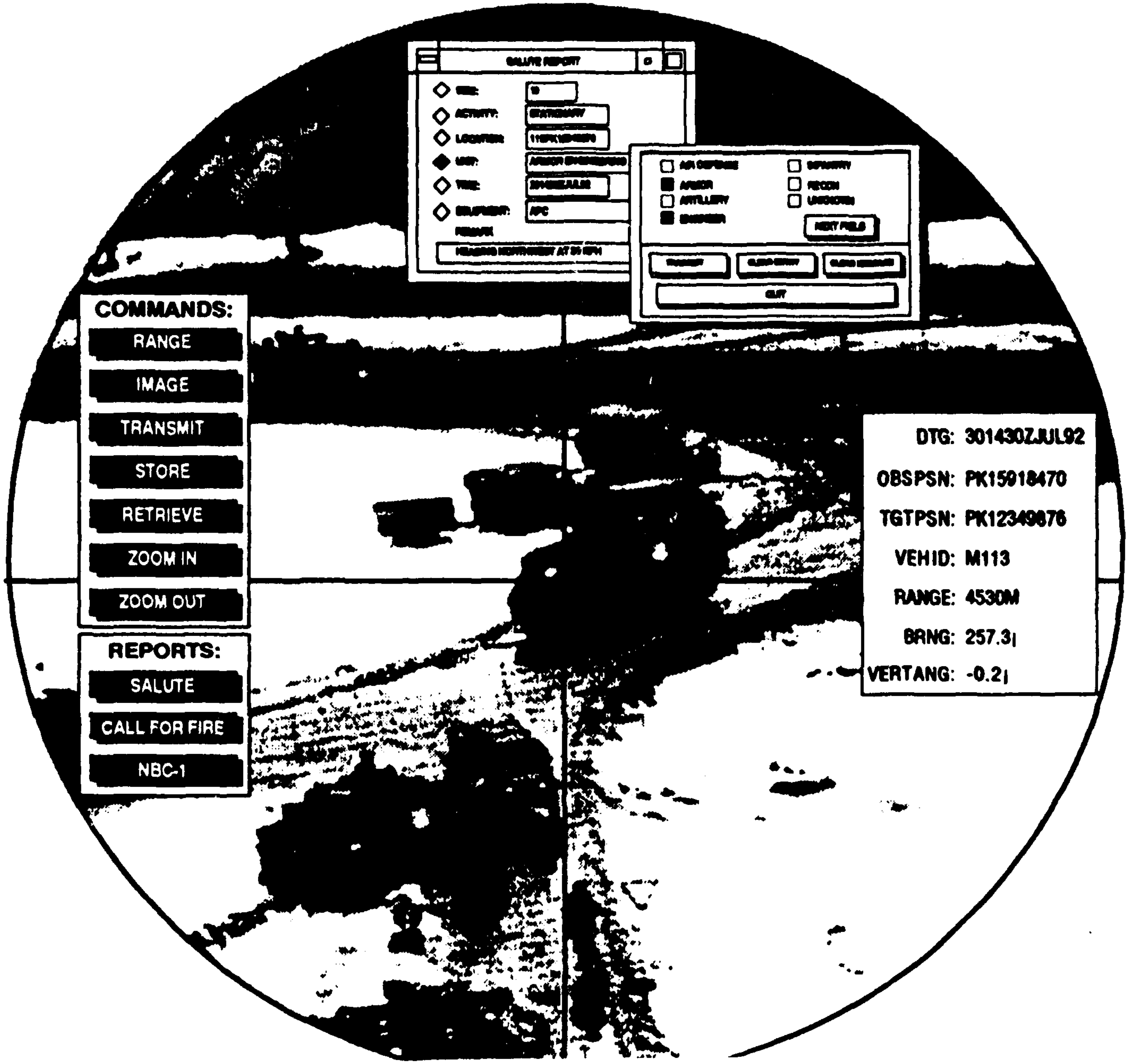
rev 8/7/92

INTELLIGENCE COLLECTION/TARGETING

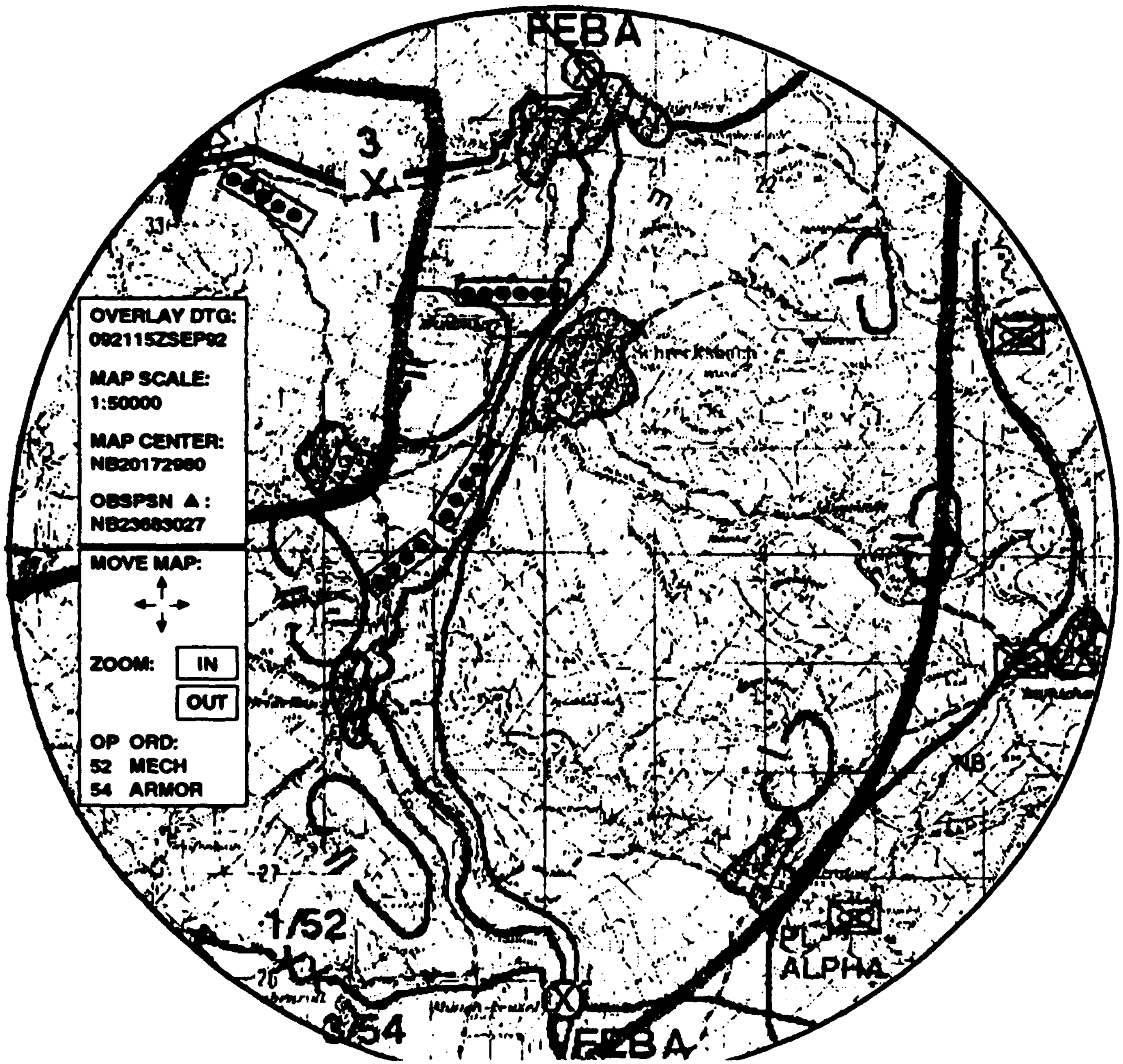


1838-10-13-92-1

OPTICAL DISPLAY



SITUATIONAL AWARENESS DISPLAY



LOW-BANDWIDTH DISTRIBUTED SYSTEMS
OPERATIONS

ESTO

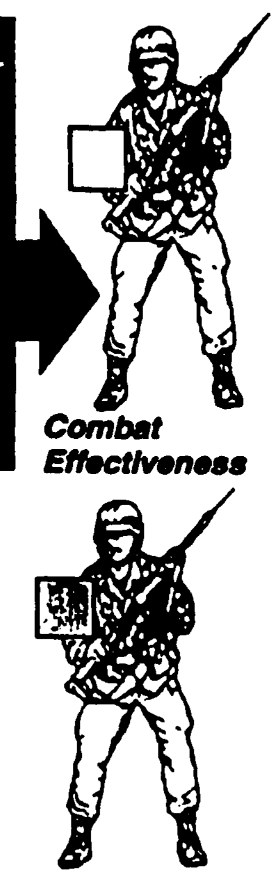
TODAY

Manual Inventory

ESTO

TOMORROW

Real Time Status



	Measurement	Rating
M16 A2 Rifle (Ea)	1	
5.56 mm Amunition (Rds)	200	
40 mm Grenades (Ea)	8	
Water (Qts)	1	
MREs (Ea)	3	
NBC Decon Kit (Ea)	0	
M-17 Mask (Ea)	1	
MOPP Suit (Ea)	2	

1838-4-9-93-3

BIOMEDICAL
UNOBTRUSIVE SENSORS

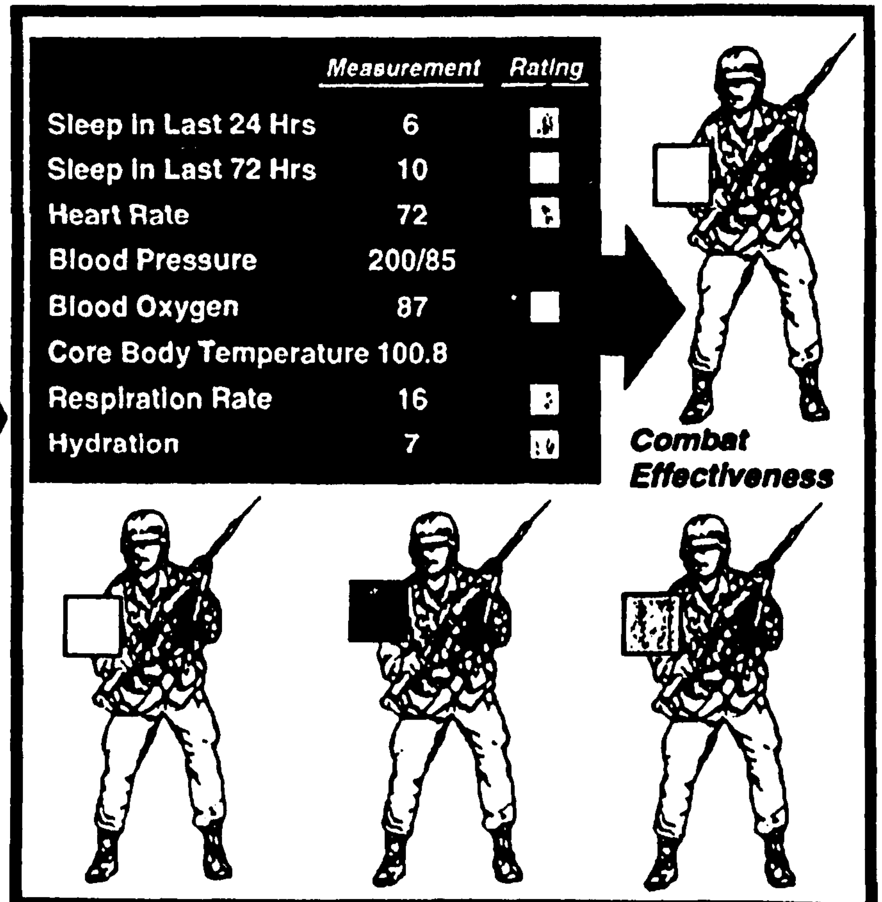
TODAY

Subjective Evaluation

ESTO

TOMORROW

Objective Evaluation



	Measurement	*Rating*
Sleep in Last 24 Hrs	6	
Sleep in Last 72 Hrs	10	
Heart Rate	72	
Blood Pressure	200/85	
Blood Oxygen	87	
Core Body Temperature	100.8	
Respiration Rate	16	
Hydration	7	

1838-10-22-92-12

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When you have a great idea,
I want you to bring it to ARPA.

ARPA

FUTURE MILITARY TECHNOLOGIES SESSION

CHAIR: MR. RONALD D. MURPHY

V

V-A AERONAUTICAL SYSTEMS

LTCOL MICHAEL S. FRANCIS

Aeronautical Systems

&

Technologies

Lt. Col. Michael S. Francis
Program Manager

Aeronautical Systems and Technologies

My name is LtCol Michael Francis. I am a Program Manager in the Advanced Systems Technology Office, and in that capacity have focused on the aeronautics arena. Let me discuss some of ARPA's current efforts dealing with aeronautical systems and related enabling technologies, as well as some of the ideas we are examining for future consideration.

ADVANCED RESEARCH PROJECTS AGENCY
3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

July 12, 1993

MEMORANDUM FOR ASTO - FRANCIS

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

Reference is made to the following material submitted for clearance for open publication:

AERONAUTICAL SYSTEMS AND TECHNOLOGIES

XXXXXX The above referenced material was **CLEARED** for open publication by OASD(PA) on July 9, 1993, Case No. 93-S-2492. All copies should carry the following Distribution Statement "A" as follows:

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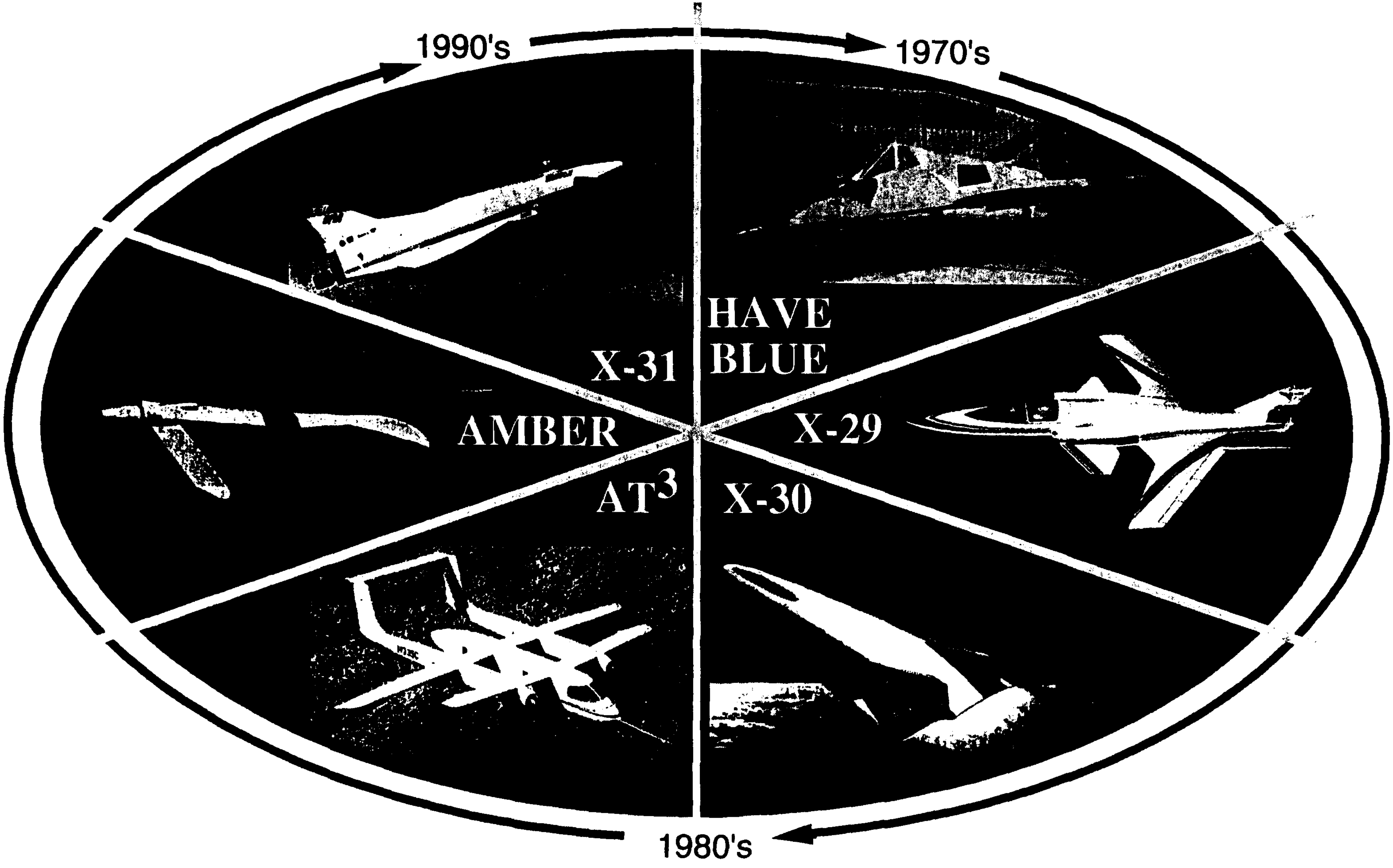
G. T. Winn
Technical Information Officer

Attachments

AERONAUTICAL SYSTEMS LEGACY



Accomplishments

On this chart I have tried to capture some of the accomplishments associated with the aircraft I just showed you. As I have already indicated, the HAVE BLUE aircraft was a subscale prototype for the F-117, and provided essentially a proof of concept that a stealth vehicle of this unusual configuration could, in fact, fly successfully.

The X-29 forward swept wing demonstrator has made a number of contributions during the decade of the 80's. It was the first high performance aircraft to fly successfully employing a aeroelastically tailored, all composite wing and defeated the divergence problem. It pioneered many advanced concepts for digital flight controls, being a full quadroplex, fly-by-wire aircraft. It spent the last couple of years of its lifetime pioneering high angle-of-attack flight with its unusual flight control system. Most recently, it became the first aircraft to attempt to exploit the vortices generated near the nose of the aircraft for control purposes by using active blowing techniques.

The X-30 National Aerospace plane, while never developed, was the focus for a number of successful flight technology developments which will ultimately be useful in achieving practical hypersonic flight.

The Advanced Technology Tactical Transport validated several unique concepts. This demonstrator sought to achieve high-speed, long-range, and STOL (Short Take-off or Landing) characteristics in a single design. It made maximum use of existing technologies in a twin engine tandem wing design that makes the low altitude innovative long range mission feasible. The flight test program also validated the concept of demonstrating new technologies in a sub-scale prototype before employing them in a production airplane.

The Amber unmanned air vehicle demonstrated the ability to build a rapidly fieldable UAV for operational purposes. It also achieved high altitude endurance capabilities necessary to accomplish its mission.

Accomplishments

★ **HAVE BLUE**

- Prototype (Subscale for F-117)
- Stealth 'Proof of Concept'

★ **X-29 Forward Swept Wing Demonstrator**

- Aeroelastic Tailoring of Composite Structures
- Advanced Digital Flight Controls / Concepts
- High Angle-of-Attack Flight
- Advanced Aerodynamic Controls

★ **X-30 National Aerospace Plane**

- Focus for Hypersonic Flight Technologies

★ **Advanced Technology Tactical Transport**

- Twin Engine Tandem Wing Design Concepts
- Rapid, Subscale Prototyping Concepts

★ **Amber**

- Rapid, Fieldable UAV
- High Altitude Endurance Demonstrated

X-31: A New Dimension in Agility and Control

Let me focus briefly on the accomplishments and plans for the X-31 Enhanced Fighter Maneuverability, or EFM demonstrator, currently in flight test at Edwards Air Force Base, California. The X-31 is unique in concept. The effort is conducted by an international, multi-agency organization known as the International Test Organization (ITO), comprised of ARPA, the US Navy, US Air Force, NASA (Dryden Flight Research Facility), the German Government, including the Luftwaffe, and the two development contractors - Rockwell International's North American Aircraft division, and Deutsche Aerospace, formerly Messerschmitt Bolkow-Blohm.

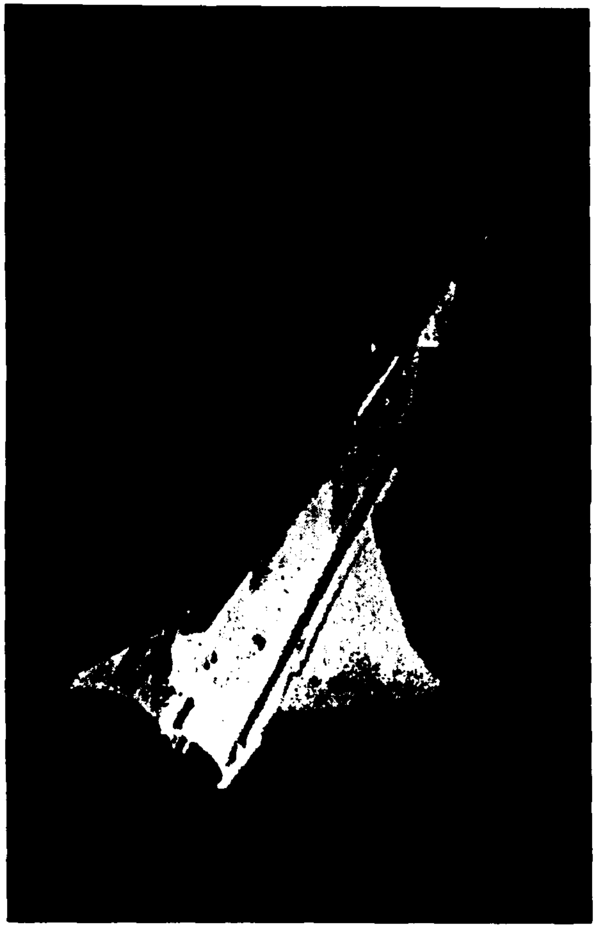
The X-31 has been flying since 1990 and has made several notable contributions to the advancement of manned flight. It has successfully integrated advanced aerodynamic and propulsion controls to achieve a full vectored thrust capability. This unique, propulsion-driven form of control is truly an alternative concept for force and moment generation. As implemented on the X-31, this control scheme is transparent to the pilot, so that he can effect vehicle maneuvering using traditional stick and rudder concepts. Having successfully accomplished this technological feat, the aircraft has been involved in pioneering the high angle-of-attack portion of the flight envelope. Although successful flight in this arena is important, the X-31 attempts to make an additional step - specifically, the achievement of agile, post-stall flight, which might be used for an edge in close-in combat. The ability to fly in this heretofore unavailable portion of the flight envelope has a number of other applications, including enhanced flight safety for vehicles equipped with the basic technologies.

The X-31 is just beginning to exploit this agility by initiating a number of flights where it will serve as an operational fighter surrogate, confirming the tactical benefits derived from past simulations, and exploring new ways to use the technologies in close-in air combat. In this respect, it is a unique experimental aircraft.

We are also attempting to integrate an advanced helmet-mounted display in the X-31, providing enhanced situation awareness for the pilot under these unusual flight conditions. That display system employs several candidate symbologies as well as 3D audio in the helmet to achieve the objectives.

Finally, we hope to demonstrate the use of thrust vectoring at supersonic speeds for stabilization and trim of the aircraft. This experiment will involve negating the effect of the vertical stabilizer and using the other aerodynamic control surfaces to achieve "quasi-tailless" flight. The ability to use advanced thrust vectoring concepts in this high-speed arena will serve as a catalyst for new, low drag and weight designs which also possess inherent low observables capability due to their much simplified aerodynamic configurations.

X-31: A New Dimension in Agility and Control



- ☆ Integrated Vectored Thrust Control
- ☆ Agile, Post Stall Flight
- ☆ Combat Benefits Demonstration
  - — Close-In Tactics
  - — Advanced Displays
- ☆ Supersonic, Quasi-Tailless Flight

Defense Environment in the 90's

The forces which shape aeronautics in the future are expected to be much different than those that have traditionally shaped it in the past. The demise of the Soviet threat, and the new awareness of more dispersed and diverse threats worldwide, will lead to new approaches for defense aeronautical systems. However, the largest single factor influencing the defense systems development equation in the foreseeable future is the level of resources which can be brought to bear on defense needs. I listed a number of these on the chart - all emanate to some degree from the limitation of resources which we have encountered and continue to expect.

Our reduced force structure will force us to reconsider the traditional military equation and consolidate missions which may have been overlapped or duplicated in the past. There will be more emphasis on mobility and power projection, both through land and sea-based air power. This is primarily due to our inability to maintain the extensive foreign basing which we have enjoyed in the past. We have also seen in recent years the need for a quick reaction capability to respond to crises throughout the globe and that requirement is not likely to change in the foreseeable future. As I indicated, we can expect more integration of service missions, and more focus on joint operations, both to fine-tune our war fighting capabilities and to optimize our reduced force. Budget constraints will force fewer field exercises, forcing us into developing new ways to train our troops and to maintain readiness.

Finally, the need to rapidly and successfully conclude a myriad of forms of conflict is a key objective. This decisiveness is not only key to reducing our losses in men and material, but also to avoid the costs of protracted conflict.

Defense Environment in the 90's

- **Reduced Resources**
- **Reduced Force Structure**
- **Emphasis on Mobility and Power Projection**
  - Limited Forward Basing
  - Quick Reaction Requirements
- **Emphasis on Joint Operations**
  - Fewer Live Field Exercises
- **Rapid, Decisive Conflict Resolution Desired**

Technology Tools for Affordable Development

Let me now focus on several specific needs which can help us build more affordable air vehicles. The technology tools which we seek should help us not only build the new system, but should also impact how we choose it, how we buy it, and ultimately how we own it. Much has been said about integrated product process development over the last few days. We, of course, are interested in the enabling tools which can facilitate and further optimize this process. These include not only the computer-aided tools alluded to by others in earlier discussions, but also processes which fuse the design and manufacturing efforts and make maximum use of the inherent raw materials being considered. Maybe we ought to consider creating a 'developer's associate', much in line of the pilot's associate concept developed by ARPA several years ago. Other tools with which you've now become familiar include advanced distributed simulation and low cost prototyping - both have application to air vehicle systems development. In short, anything that helps leverage the many products of this information age in a positively productive way should be exploited for their use in value in affordable aircraft development.

Technology Tools for Affordable Development

Choose - Build - Buy - Own

★ **Integrated Product - Process Development (IPPD)**

Enablers

- Concurrent Engineering Aids
- Design - Process - Materials Synergy
- 'Developers Associate'

★ **Advanced Distributed Simulation (ADS)**

★ **Low Cost Prototyping Processes**

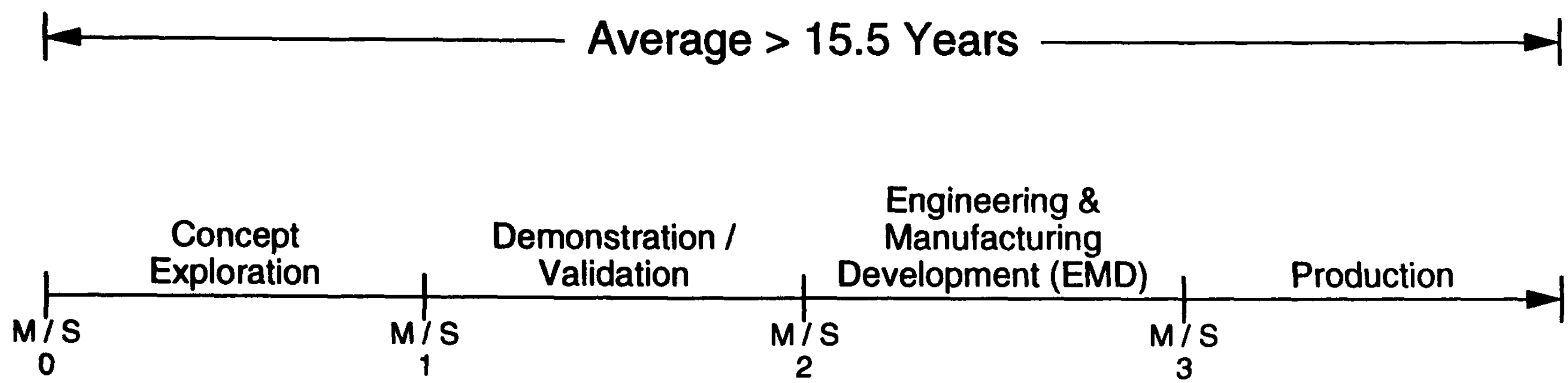
★ **'Information Age' Levers**

The Acquisition Timeline

The current development process as employed by DoD is a cumbersome one. The average development cycle for a system today is approaching sixteen years and growing.

The Acquisition Timeline

TODAY:



Advanced Distributed Simulation for Acquisition (1)

In this chart, I've tried to depict the use of Advanced Distributed Simulation in the acquisition process itself.

Early in programs, ADS can be employed for evaluating concepts within an overall mission context, with an eye toward selecting the most desirable concept. In this application, it can also facilitate early involvement of the ultimate system user, and can help integrate unique requirements early in the development process.

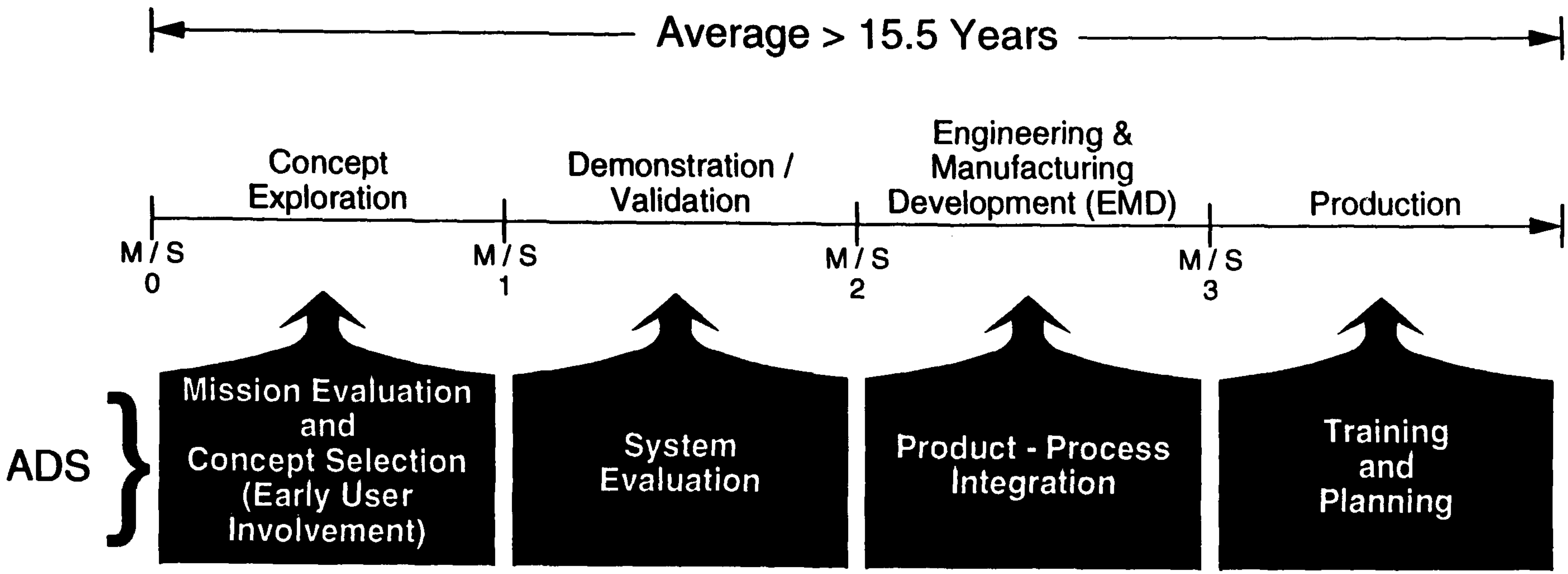
In the demonstration and validation phase, ADS can be used to evaluate the evolving system, again in a broad mission context. Some of the same simulation tools can be employed to provide those functions which need not be built into the physical prototype/demonstrator.

Properly exploited, ADS has the potential to influence the integration of product design and manufacturing processes all the way up to final assembly of the vehicle. Properly exploited, this capability may help shorten this phase of the program significantly. This is one of the least well understood applications of ADS.

Even in the final phase of production, Advanced Distributed Simulation can play an important role as a training tool for the user community, as well as a planing tool for the operational user. It may also be used to investigate the value of various potential candidate upgrades on mission effectiveness.

Advanced Distributed Simulation for Acquisition

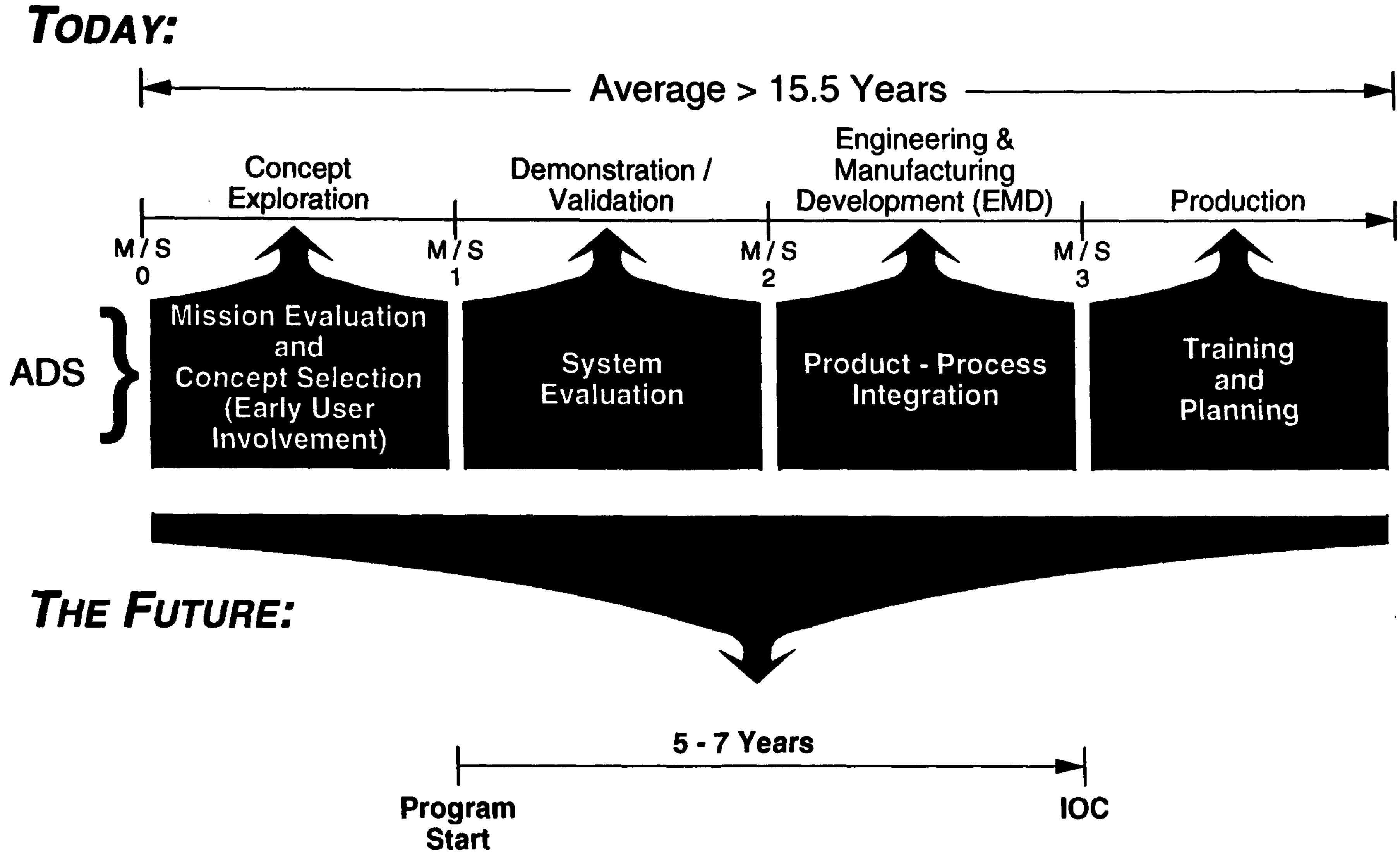
TODAY:



Advanced Distributed Simulation for Acquisition (2)

Moreover, properly implemented, we believe that ADS can help to reduce the length of the acquisition cycle to a much more palatable and more affordable five to seven years, if exploited with other concurrent engineering tools. I am currently involved in the Affordable Aircraft Acquisition Study sponsored by ARPA and DoD, where we are looking at methods and potential initiatives that will allow us to do this.

Advanced Distributed Simulation for Acquisition



Intelligent Systems

Another major area of importance is that of intelligent systems as they relate to air vehicles. The significance of superb situational awareness should come as no surprise given ARPA's emphasis in this area. These systems can also help reduce the workload of today's overstressed crews operating in a combat environment. Our real motivation here is to provide for rapid and accurate decisions which help <u>win</u> the conflict. And of course, the same tools which accomplish the above can also be exploited to improve training and evaluation of our crews.

Let me now provide an example of a program which we are considering in this area.

Intelligent Systems

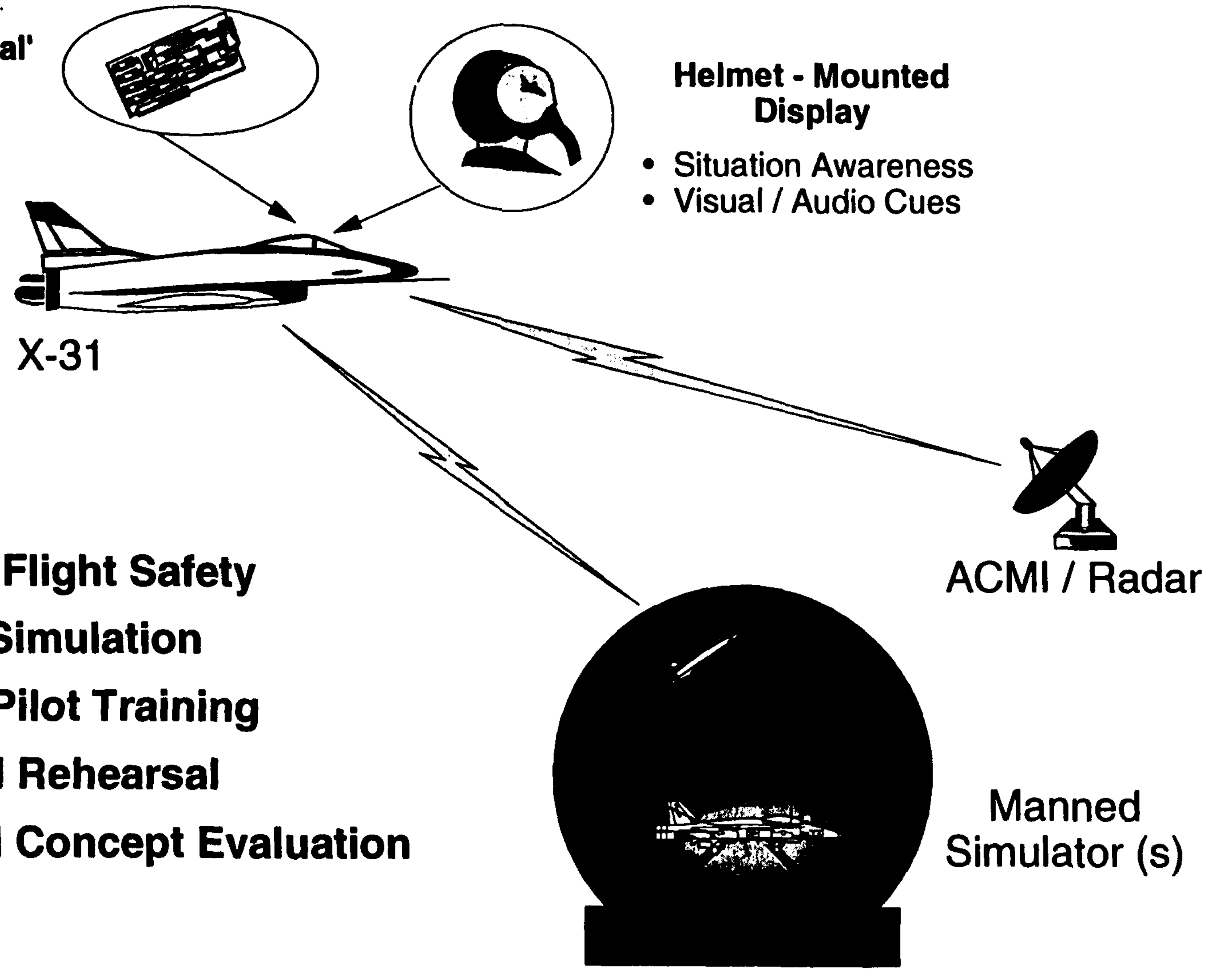
- ★ Provide Superb Situation Awareness
- ★ Reduce Pilot / Crew Workload
- ★ Enable Rapid, Accurate Decisions
- ★ Improve Training and Evaluation

Virtual Adversary Initiative

This initiative is really an extension of our efforts with the X-31 in the Advanced Displays area. If implemented, the capability described here would allow the pilot of a real aircraft to engage a virtual adversary, either a domed simulator or an on-board 'embedded' opponent in a close-in 'visual' engagement. An advanced helmet-mounted-display, employing both visual and audio cues, becomes the simulator environment for the pilot of the real vehicle. The ability to overlay the virtual world and the real world is key to successfully developing this technology.

The many benefits are listed in the lower left of the chart and range from improved flight safety by eliminating mid-air collision possibilities, to the ability to evaluate new concepts against real current day combatants.

Virtual Adversary Initiative



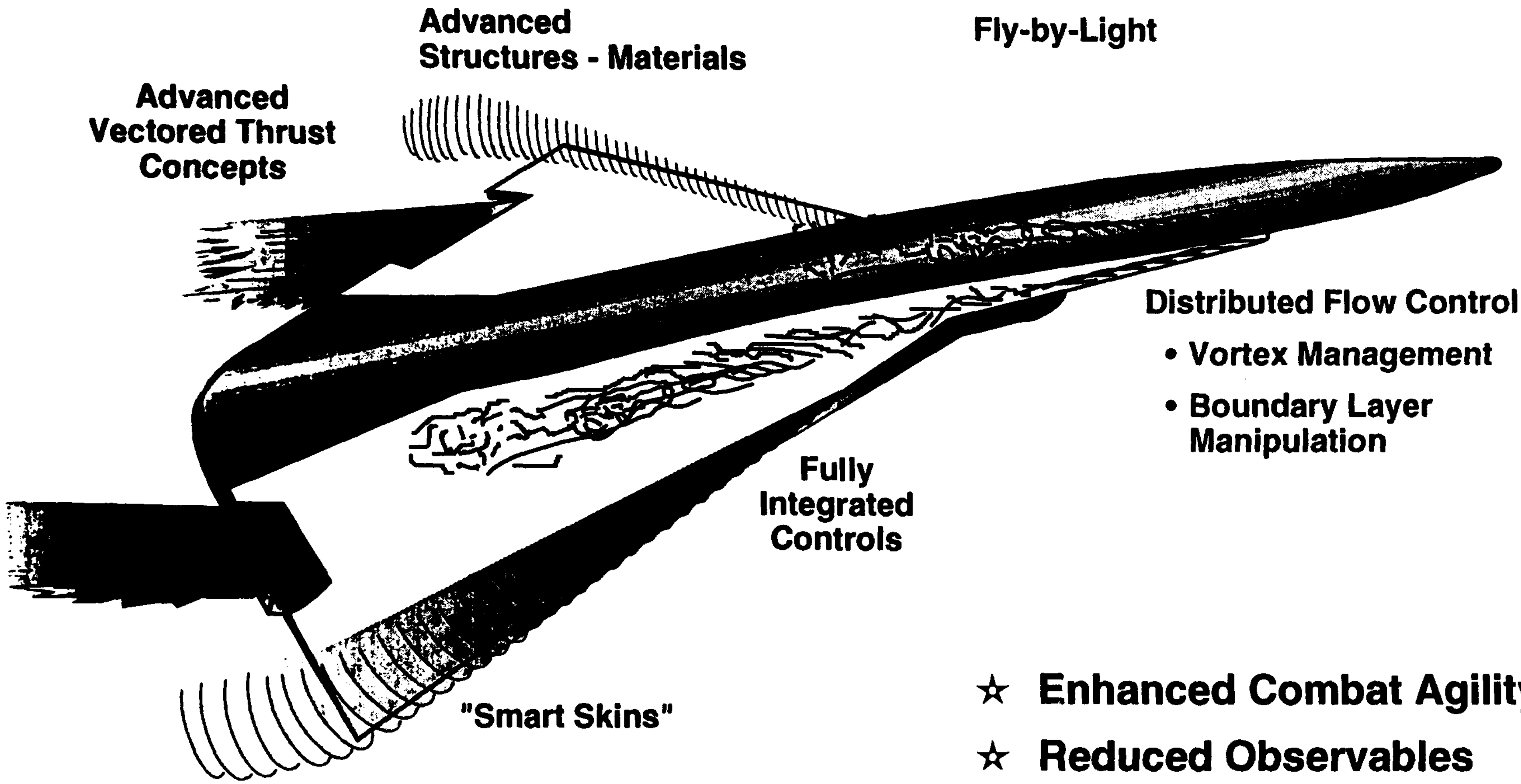
- ☆ **Improved Flight Safety**
- ☆ **Realistic Simulation**
- ☆ **Effective Pilot Training**
- ☆ **Battlefield Rehearsal**
- ☆ **Advanced Concept Evaluation**

Emerging Performance Technologies

A third area I would like to touch upon is in the area of performance, and I use that term in the broadest sense. We have always maintained our military superiority, not in numbers, but in the strength of our technological edge. Most of the time, that capability translates into enhanced performance. Although the threat today is more diverse, there is no reason to believe - with the spread and proliferation of advanced technology in the third world - that the equation will change in the near term. I've tried to capture just a few of the vehicle technologies that may make the difference in performance for advanced combat aircraft.

A number of these have been addressed by others during this three day conference. Let me focus on two that have not been discussed. The areas of distributed flow control and advanced vectored thrust concepts collectively represent a new way to control the vehicle environment - an alternative way to generate the forces and moments which govern flight. Distributed flow control is a subject which has received much attention in this country's research laboratories for the better part of two decades. The ability to implement these concepts inflight through other enabling technologies has only recently begun to emerge. The area of vectored thrust is perhaps more familiar to you, but it too is a long way from a mature concept.

Emerging Performance Technologies



☆ Enhanced Combat Agility

☆ Reduced Observables

☆ Increased Range / Efficiency

THE CHALLENGE: A SIMPLER, MORE EFFECTIVE AIR VEHICLE

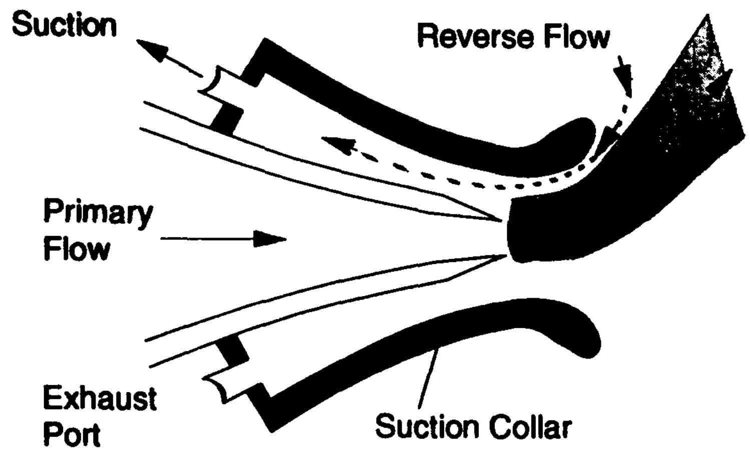
Counterflow Thrust Vector Control

Let me give you an example of the latter. In the 2D nozzle concept shown on the chart, a jet issuing into the ambient laboratory environment emanates from a unique nozzle design. A reverse flow produced by a very small amount of suction at the nozzle collar at one edge of the jet has been observed to linearly deflect the jet up to angles as high as 25° at high speeds. Specifically a Mach 2.2 jet has demonstrated 25° of vectoring capability**. An important feature of this concept is that there are no moving parts in the nozzle area. Presumably, the fluid valve which drives the system can be also designed with few moving parts. Key attributes of this design include an inherent wide band response - a capability required for application to high speed, high Mach number flows. It is therefore a potential key ingredient to vectoring at supersonic speeds.

**Results are courtesy of Y. Krothapalli, Florida State University

Counterflow Thrust Vector Control

Jet Flow / Ambient Surroundings



Vectoring Mechanics

- ☆ **Improved Mechanical Efficiency**
  - **Fewer / No Moving Parts**
- ☆ **Wideband Response for High Speed Flight**
- ☆ **Linear Vector Angle Control**

Flow Visualization

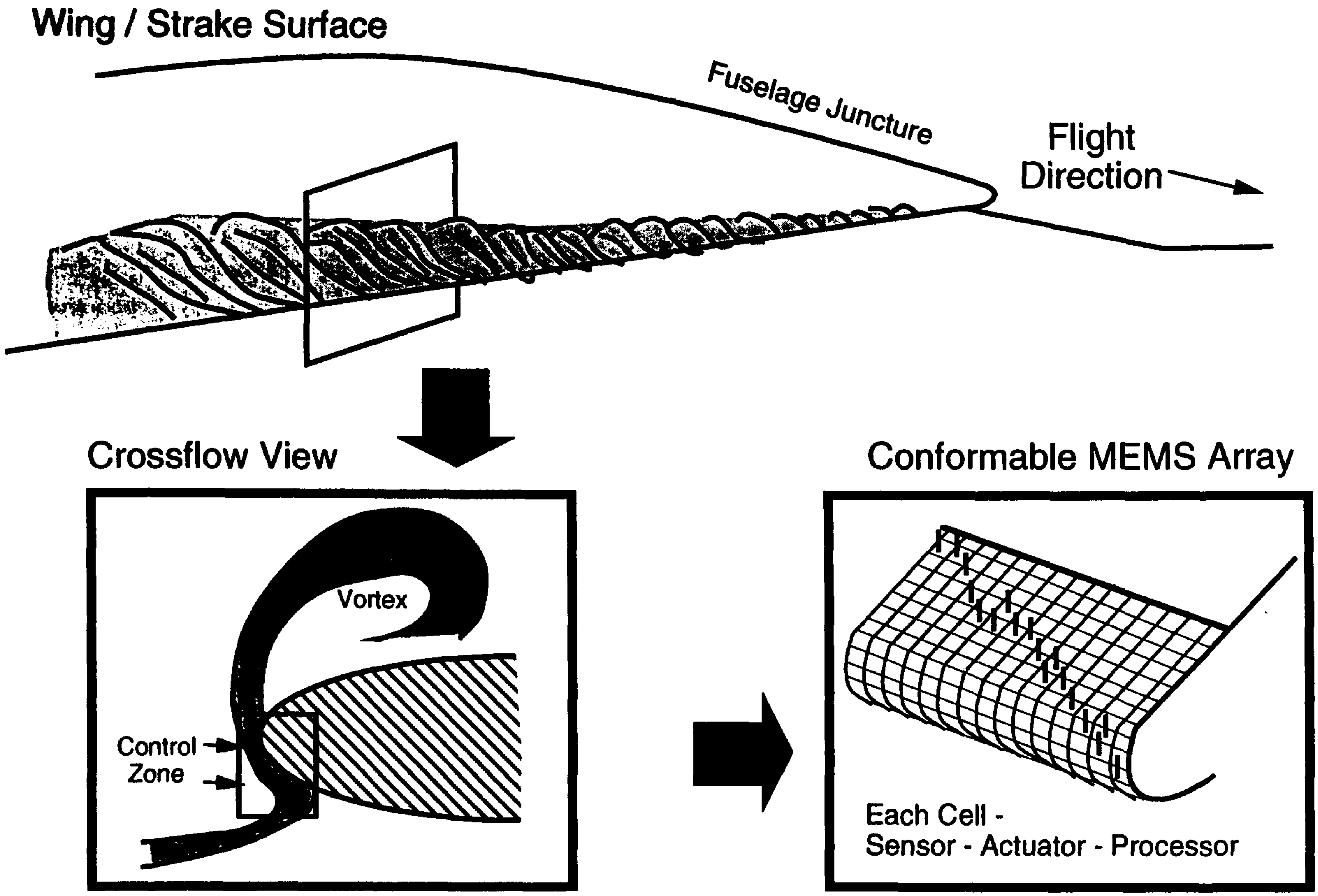
Mach 2.2 Jet (Without Vectoring)

Mach 2.2 Jet (25 Vectoring)

MEMS for Vortex Management

You have already been acquainted with the revolution in Micro Electro Mechanical Systems as described by Ken Gabriel from ESTO. In collaboration, we are currently looking at the feasibility of using large MEMS rays to provide a measure of distributed flow control. In this example, (courtesy of C.M. Ho (UCLA) and Y.C. Tai (California Institute of Technology) a conformable MEMS array consisting of sensors, actuators, and processors, all neurally-netted and interspersed over a surface of modest size, is applied to the leading edge of a swept wing. By using the sensing capability to locate the stagnation zone and the flow separation line, MEMS actuators will be used to alter the separating shear layer characteristics and influence downstream vortex behavior. The result would be either an enhancement or degradation of local forces which could provide lift augmentation or reduction, again, with no macroscopic moving parts. This simple laboratory experiment could lead to alternative ways of effecting flight if many other implementation issues can be resolved. This represents a more long term application of distributed flow control technology.

MEMS* for Vortex Management



* Micro Electro Mechanical Systems

Advanced Systems Concepts

Let me now focus on some of the conceptual arrangements which are both timely and appropriate for the current defense environment.

The notion of a reconfigurable aircraft is not really a new one. Software reconfigurability as applied to today's digital aircraft flight control systems is achievable today. The ability to achieve similar results in hardware may be possible with the proper exploitation of advanced materials and their structural constructs. It may be useful to consider whether this reconfigurability should occur in the field or on the production line, from an affordability perspective.

A second area demanding attention is the area of innovative unmanned systems. A number of enabling technologies are close at hand to make these types of systems more capable and versatile. As our concern for putting man in harms' way increases, the alternative of using unmanned systems becomes attractive. There is no reason to preclude their use in operational missions where their performance may actually outstrip that of a manned vehicle. In addition, these types of systems can be a logical solution to testing high risk concepts or pioneering new methods of flight.

Another area worthy of mention, is in the area of vehicle-weapons synergy. Historically, we have developed vehicles independent of the weapons with which they must integrate and deploy. The ability to develop both together may lead to a more effective, more affordable solution. Again, not surprisingly, the word affordable appears as a bottom line.

Advanced Systems Concepts

- ❑ **Reconfigurable Aircraft**
  - Hardware
  - Software
  - Production Line vs Field
- ❑ **Innovative Unmanned Systems**
  - New Operational Missions
  - Risk Taking 'Pioneers'
- ❑ **Vehicle - Weapons Synergy**
- ❑ **Affordable Solutions**

ASTOVL Demonstration - The Next Challenge

ARPA's potential next major program in the air vehicle area is the Advanced, Short Take-off or Vertical Landing System. The ASTOVL demonstrator has both the performance capability and the flexibility to operate in diverse environments and with a multitude of applications. Its many attributes will help it become a decisive war fighter as well. Finally, this ARPA program will become a model for affordable development of air vehicle systems in the future.

ASTOVL* Demonstration — The Next Challenge

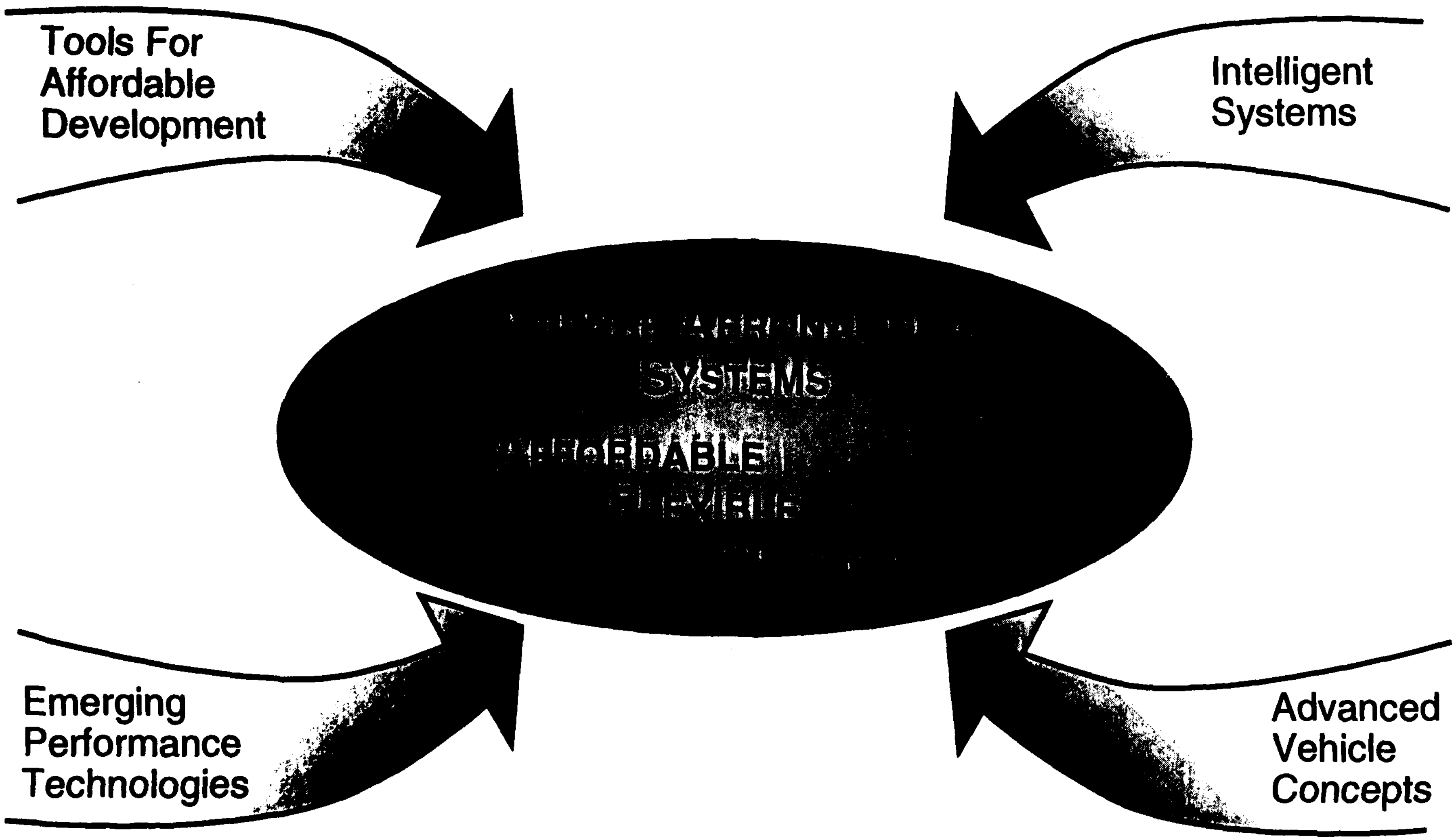
- ☆ Supersonic Capability
- ☆ Flexible Basing
- ☆ Multi-Service Applications
- ☆ Survivable Warfighter
- ☆ A Model for Affordable Development

* Advanced Short Takeoff / Vertical Landing

Aeronautical Systems and Technology

The collection of ideas I've just described, including the suite of technologies and concepts, are all potential ingredients for retaining our superiority in performance by developing aeronautical systems which are flexible in application and part of a decisive warfighting capability. They can also help create more affordable systems in a decreasing resource environment.

Aeronautical Systems & Technology



V-B LAND COMBAT SYSTEMS

MR. THOMAS HAFER

ADVANCED LAND SYSTEMS

Presented by

Mr. Thomas F. Hafer
ARPA/ASTO

1276-5-25-93-5

ADVANCED LAND SYSTEMS

GROUP RATIONALE

- U.S. land forces may face situations of non-supremacy
- Land operations are still necessary for
  - Taking/holding real estate
  - Urban warfare
  - Jungle warfare
  - Guerilla warfare

The goal of ALS is to develop technologies and systems capable of providing a decisive advantage to land forces comparable to that of air, space, and sea forces

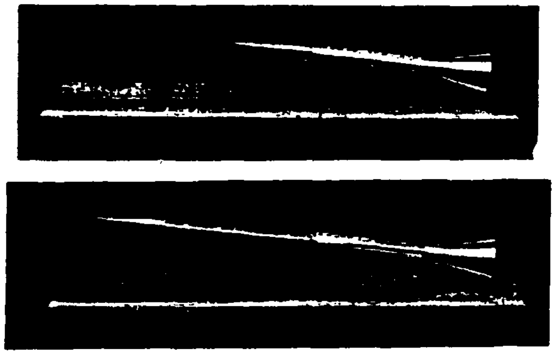
1276-5-25-93-1

This presentation will overview the programs in the Advanced Land Systems (ALS) group within the Advanced Systems Technology Office (ASTO). ALS has recently been re-organized within ASTO, and is reviewing current and potential future directions. We believe that ground forces are still required for a number of likely situations, but that they generally do not have an overwhelming technological advantage versus their potential adversaries such as that enjoyed by air and sea forces. Our goal is to provide significant increases in ground force capabilities through improved effectiveness and affordability.

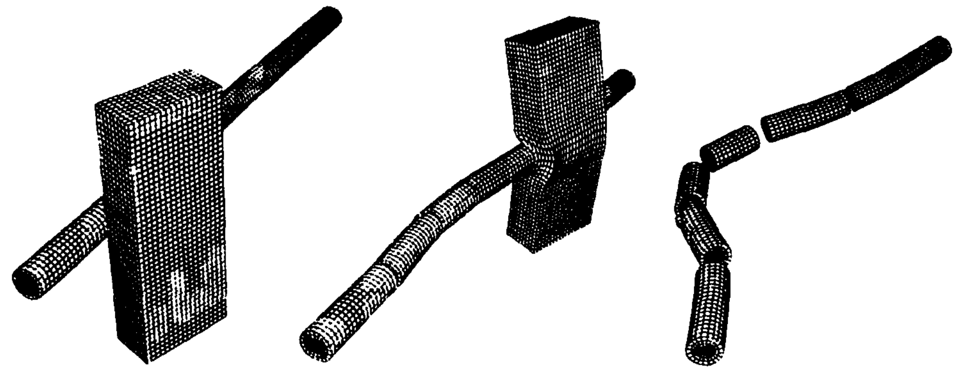
ADVANCED LAND SYSTEMS

RECENT ACCOMPLISHMENTS IN ADVANCED LAND SYSTEMS

Kinetic Energy Penetrator that Extends in Flight for Deep Penetration (Lawrence Livermore National Laboratory)



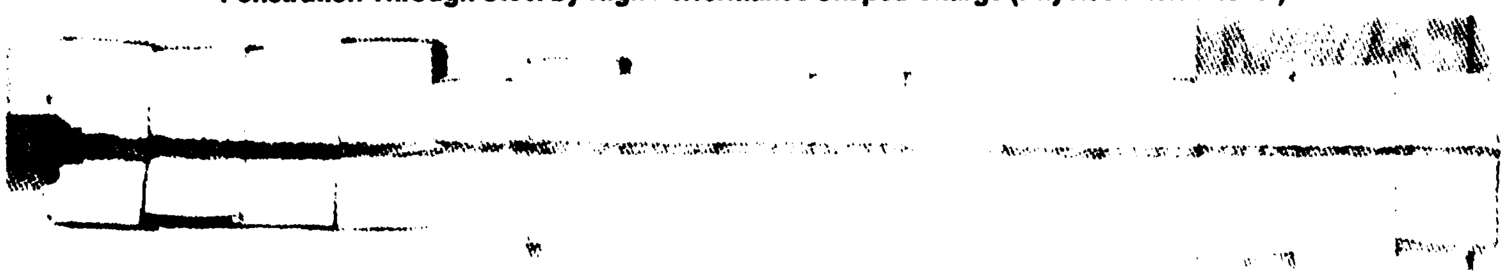
Advanced Computational Mechanics for Rapid, Enhanced Design (Lawrence Livermore National Laboratory)



High Speed Shaped Charge Jet Formation Imaged by Advanced Diagnostics (Lawrence Livermore National Laboratory)

Light Applique System Technique (LAST) Armor Being Applied to USMC Light Armored Vehicle (Foster-Miller, Lanxide)

Penetration Through Steel by High Performance Shaped Charge (Physics International)



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Depicted here are examples of successful programs developed by the group which now comprises Advanced Land Systems. The focus of these efforts was on armor/anti-armor. Shown at the upper left is a kinetic energy rod which can increase its length (and hence its penetration capability) in-flight, thus increasing the effectiveness of current tank guns. In the lower right is a picture of a novel up-armoring kit which allows tailoring of armor protection in response to a new threat or situation. At the upper right is a computer graphic of a simulated interaction between a rod penetrator and a flying armor bar. This situation correlated well with test results.

At the lower left is a high-speed photograph of a shaped charge forming. These photographs are extremely useful in diagnosing the characteristics of a new design. At the bottom is a stack of sectioned 4" thick steel slabs which have been perforated by a shaped charge similar to the one shown above.

ADVANCED LAND SYSTEMS
CURRENT PROGRAMS

- **Contingency Technology**
  - Deployability
    - *Light Contingency Vehicle*
    - Turbo Roto Compound Engine
    - Anti-Helicopter Mine
  - Lethality
    - X-Rod
  - Survivability
    - Unconventional Survivability
    - Armor
  - *Battle Management*
    - Commercial Communications Technology Testbed
- **Cost and Burden Reduction**
  - Affordability
    - Integrated Process and Product Design
  - Operations and Environment
    - Electric/Natural Gas Vehicles

1276-5-25-93-2

This chart lists current programs within ALS. Our current foci are in two areas: contingency technologies which enhance the effectiveness of air-deployable rapid-response forces, and cost and burden reduction which aims at processes and systems to allow more affordable production and lower operating costs. Several of these programs have been on-going for several years, and are nearing the end of ARPA's participation. The remainder are relatively new programs. Rather than discussing each program, the remainder of this presentation will address our vision for two relatively new areas: the Light Contingency Vehicle, and Battle Management.

ADVANCED LAND SYSTEMS

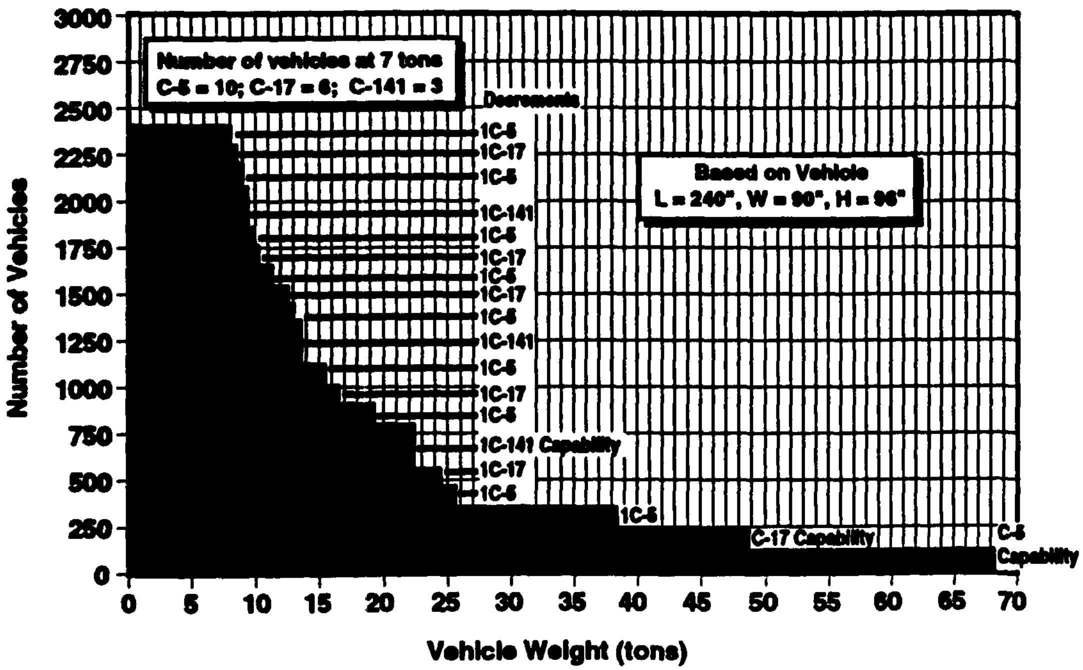
VISION FOR LAND COMBAT VEHICLES

Current Status

- When rapid response is needed
  - Heavy vehicles are difficult to deploy by air
  - Light vehicles are vulnerable to many weapons, are at a disadvantage versus heavy armored forces

The challenge is to provide high survivability, lethality, and effectiveness on a lightweight air-deployable vehicle

Intertheater Airlift Capability vs. Vehicle Weight Growth
From 7 to 70 Tons



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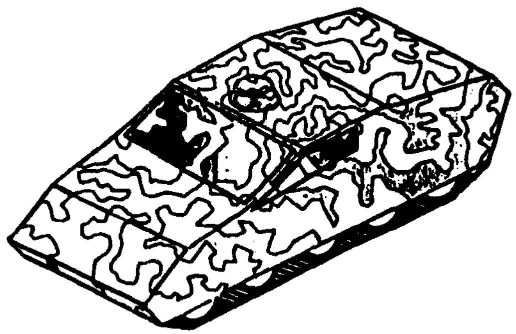
Current forces consist of medium and heavy armored vehicles such as the 30 ton M2 Bradley vehicle and the 65 ton M1 Abrahms tank, and light vehicles including HMMWVs and LAVs. The medium and heavy vehicles have adequate lethality and survivability, but are difficult to transport by air. This is illustrated in the graph at the lower left, which shows the total number of vehicles which could be air deployed across the ocean in all available C-5, C-17, and C-141 aircraft versus vehicle weight. There is a rapid fall-off in the area between 10 and 20 tons, and a clear advantage for remaining under 10 tons. (Note: This graph shows only the effect of the vehicles, and does not include fuel, ammunition, and other equipment.)

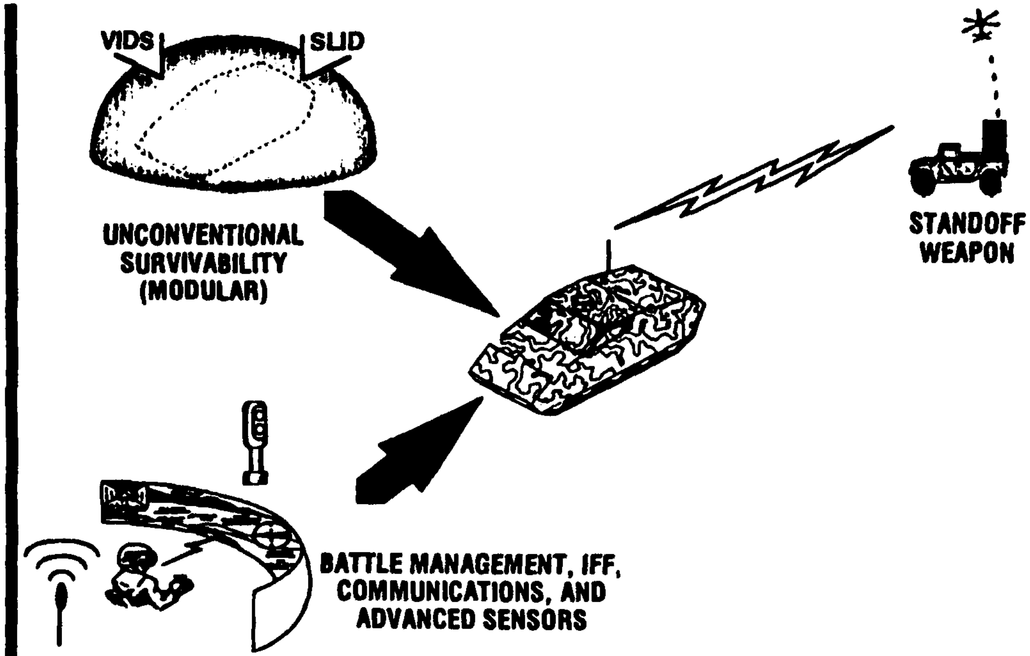
A HMMWV with a missile launcher such as employed by current airborne divisions is shown at the right. This system is highly vulnerable to artillery and small arms fire. In general, vehicles currently employed by airborne divisions are too slow, too vulnerable, or have insufficient firepower.

ADVANCED LAND SYSTEMS

LIGHT CONTINGENCY VEHICLE



- 8 TONS (BASE CONFIGURATION GOAL)
- VOLUME, POWER, AND SUSPENSION FOR A 4-TON MISSION MODULE
- INTERNAL HELO TRANSPORT (GOAL)
- BASIC ARMOR PROTECTION AGAINST ARTILLERY/SMALL ARMS
- INTERFACES FOR MODULAR ARMOR, SIGNATURE REDUCTION



- LETHALITY (AND SURVIVABILITY) VIA REMOTE "VIRTUAL WEAPON"
- SURVIVABILITY VIA ARMOR AND UNCONVENTIONAL MEANS
- MISSION EFFECTIVENESS VIA BATTLE MANAGEMENT, C^2, IFF, AND SENSORS

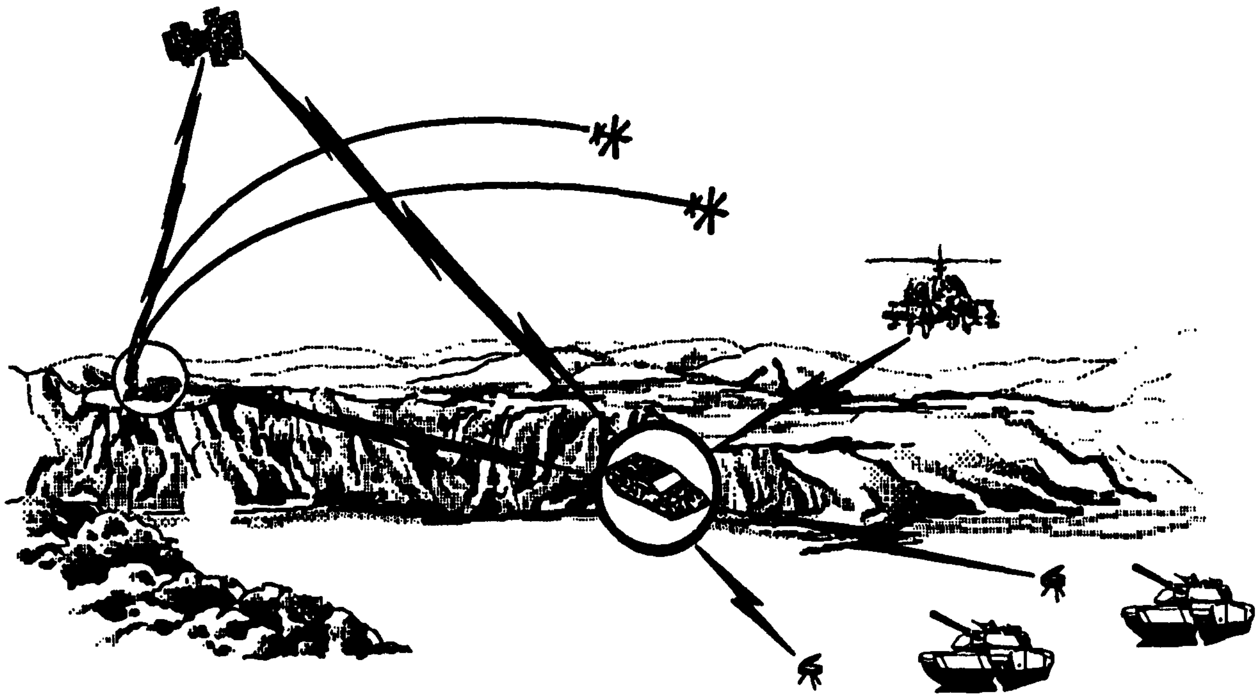
93/0528.02

Our concept and goals for the LCV are depicted here. Two aspects are addressed: the vehicle characteristics and the system concept.

The vehicle has a goal weight *of 8 tons* with a basic light armor and mission equipment suitable for a scout role, but it has the space, mobility, and layout to accommodate various mission modules such as a weapon station. In addition, the system will be constructed to accept external appliqués of armor or signature reduction systems.

The LCV will also serve as the focal point for integration of three technology groups being developed in parallel programs. Lethality will be achieved through a communication link with an off-board weapon launcher. Survivability will be achieved through a combination of modular armor and unconventional means such as hit avoidance and detection avoidance. Mission effectiveness will be enhanced via improved sensors and advanced battle management.

ADVANCED LAND SYSTEMS
OPERATIONAL CONCEPT
(S&T THRUST 5)



▷ **POTENTIAL MISSIONS**

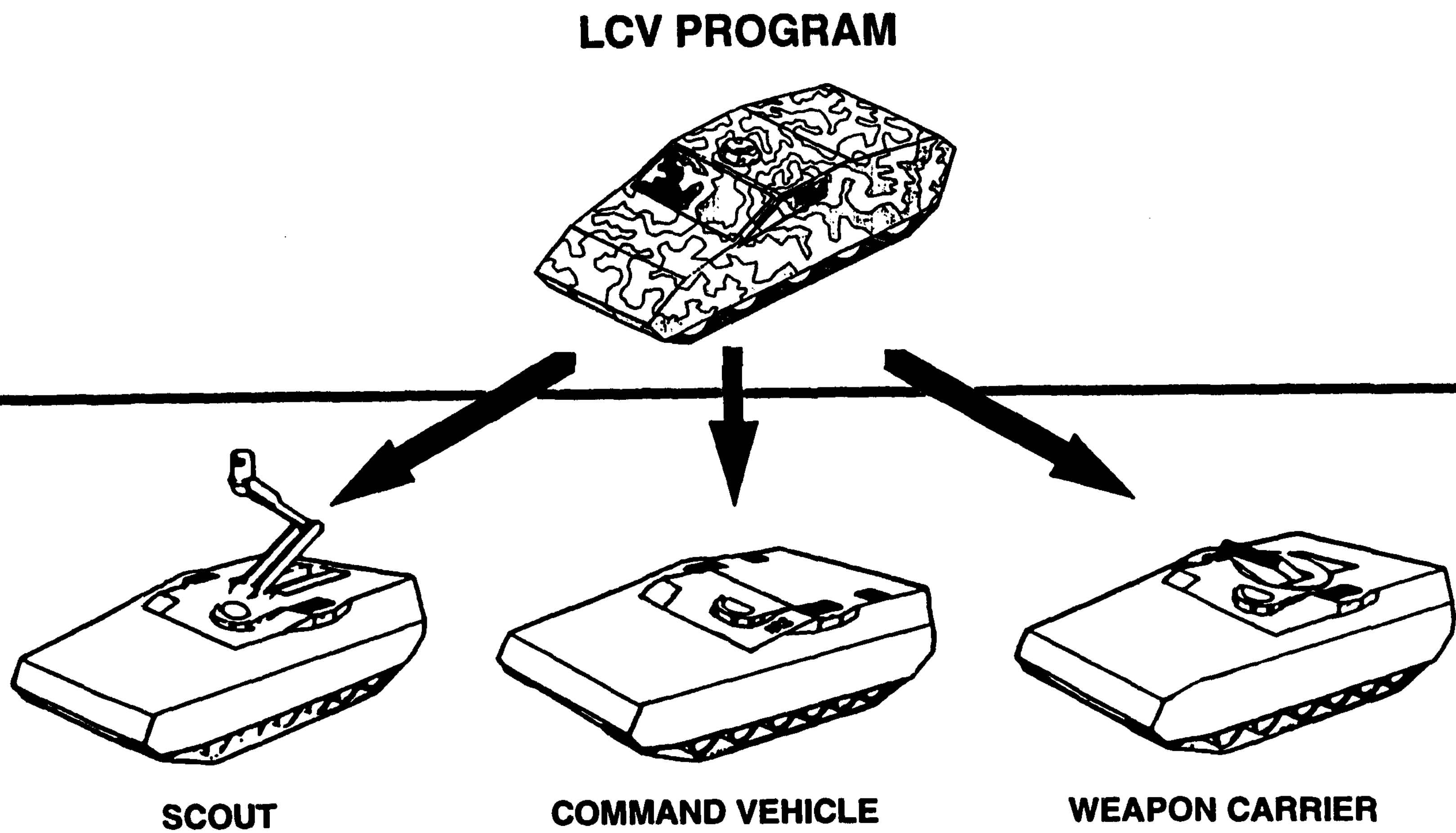
- EARLY ENTRY
  - SEIZE AND DEFEND KEY FACILITIES, eg AIR FIELDS, PORTS
  - DELAY/FIX THREAT ARMOR ADVANCES
- OPERATIONS WITH FOLLOW ON FORCES

⇒ **MAXIMIZE RATE OF BUILD-UP OF COMBAT POWER**

The operational concept for the LCV is shown here. The LCV will operate as the forward element of a hunter-killer team. LCV will provide targeting information to a missile-firing platform which will respond rapidly to calls for fire from the LCV. This concept, together with other elements depicted, will be demonstrated as part of the Science and Technology Thrust 5 Top Level Demonstration. The weapon used in the Thrust 5 demonstration will be a non-line-of-sight (NLOS) missile, however, subsequent versions could direct a variety of weapons. This concept allows a highly effective system to be air deployed, resulting in a rapid buildup of combat power.

ADVANCED LAND SYSTEMS

FUTURE MISSION VARIANTS



POSSIBLE DEM/VAL VARIANTS (EXAMPLES)

LCV is a technology development program and currently has no schedule for transition to production. It will provide the technology base development for the possible future development of a variety of light vehicles, such as the examples shown.

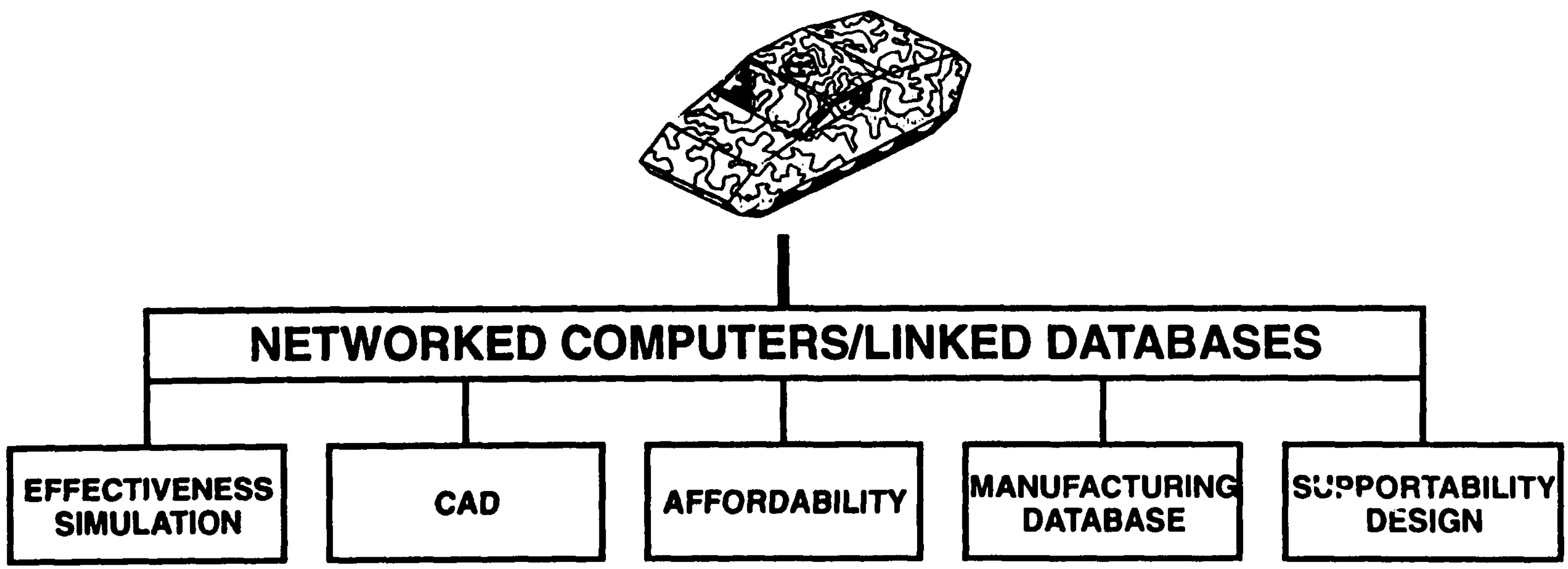
ADVANCED LAND SYSTEMS

LIGHT CONTINGENCY VEHICLE

▷ APPROACH

- 4 PHASE PROGRAM
  - TRADEOFFS/CONCEPT REFINEMENT
  - VEHICLE FABRICATION/DEMONSTRATION
  - TECHNOLOGY INTEGRATION/DEMONSTRATION
  - TOP LEVEL DEMONSTRATION

- USE INTEGRATED PRODUCT AND PROCESS DESIGN (IPPD) FOR IMPROVED AFFORDABILITY



The LCV will be developed in 4 phases. Multiple contractors will participate in the tradeoff and concept refinement phases, and will address key trades such as the preferred fabrication technique (composite versus metal), suspension (wheels versus tracks), helicopter transport requirements (internal versus external stowage), and propulsion (internal combustion versus electric hybrid). The impact of each of these on program, production, and life cycle costs will be assessed. This phase will culminate in a downselection to one contractor for vehicle fabrication and test, technology integration, and final demonstration.

Design and fabrication will employ a concurrent engineering technique called integrated product and process design (IPPD). This will automate and assist in a multi-disciplinary, simulation based approach to design with the aim of ensuring ease of manufacturing and sustainability.

ADVANCED LAND SYSTEMS
VISION FOR BATTLE MANAGEMENT

Definition

Collection	Synthesis	Application
• Sensors	• Electronic Maps	• Orders
• Intelligence	• Projections	• Monitoring
• Position/Status	• Wargames	• Fire Control Enhancement
• IFF	• Speech Synthesis	• Presentation to Soldiers
• Terrain/Met	• Language Translation	• Battle Damage Assessment
• Logistics		

COMMUNICATIONS PIPELINE

Current Status

- System has grown from the bottom up
  - Collection of networks patched together
  - Currently structured principally for voice communications
  - No unified structure to data management
  - Increased volume of data threatens to clog system

Ability to provide common, real-time, top-to-bottom, graphic-based view of the battlefield will be difficult to accomodate

1276-5-25-93-14

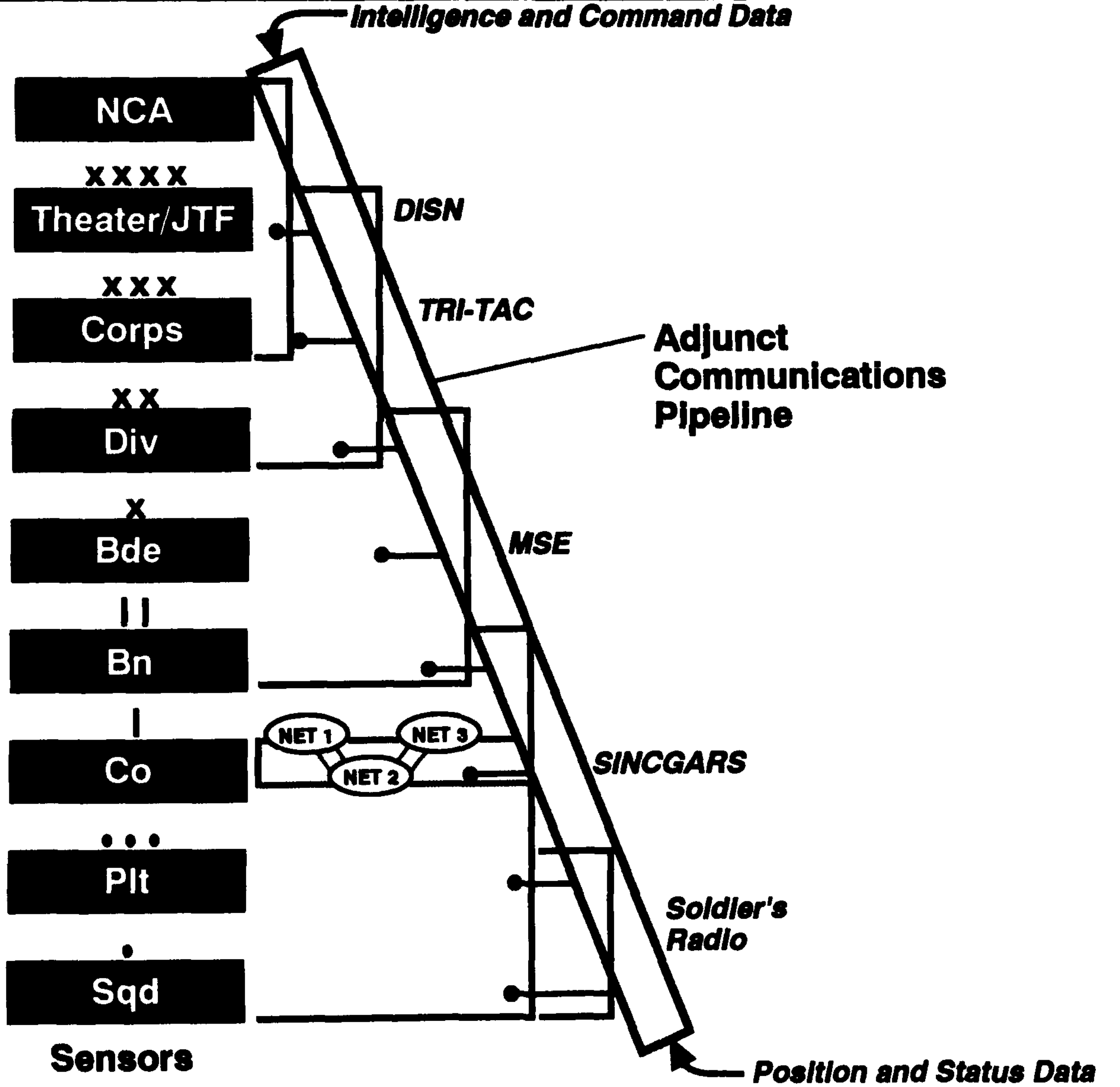
Battle management consists of the acquisition, manipulation/analysis, and distribution of information on the battlefield. Examples of these are shown at the top of the chart. To be effective, it must be timely, secure, difficult to interrupt, and must not overwhelm the recipient. Timely distribution requires an effective communication system connecting all the system nodes.

Current land combat battle management consists of separate networks which were originally intended principally for voice communications rather than data, and which cannot, by themselves, intercommunicate. Intercommunication between these networks is performed through gateways some of which are automated while others are manual. The increased information flow required for a true battle management system is likely to result in slow throughput times.

Many approaches to addressing these problems are possible. Some possible examples are given on the next three charts.

ADVANCED LAND SYSTEMS

ARMY MILITARY COMMUNICATIONS SYSTEMS DEPLOYMENT



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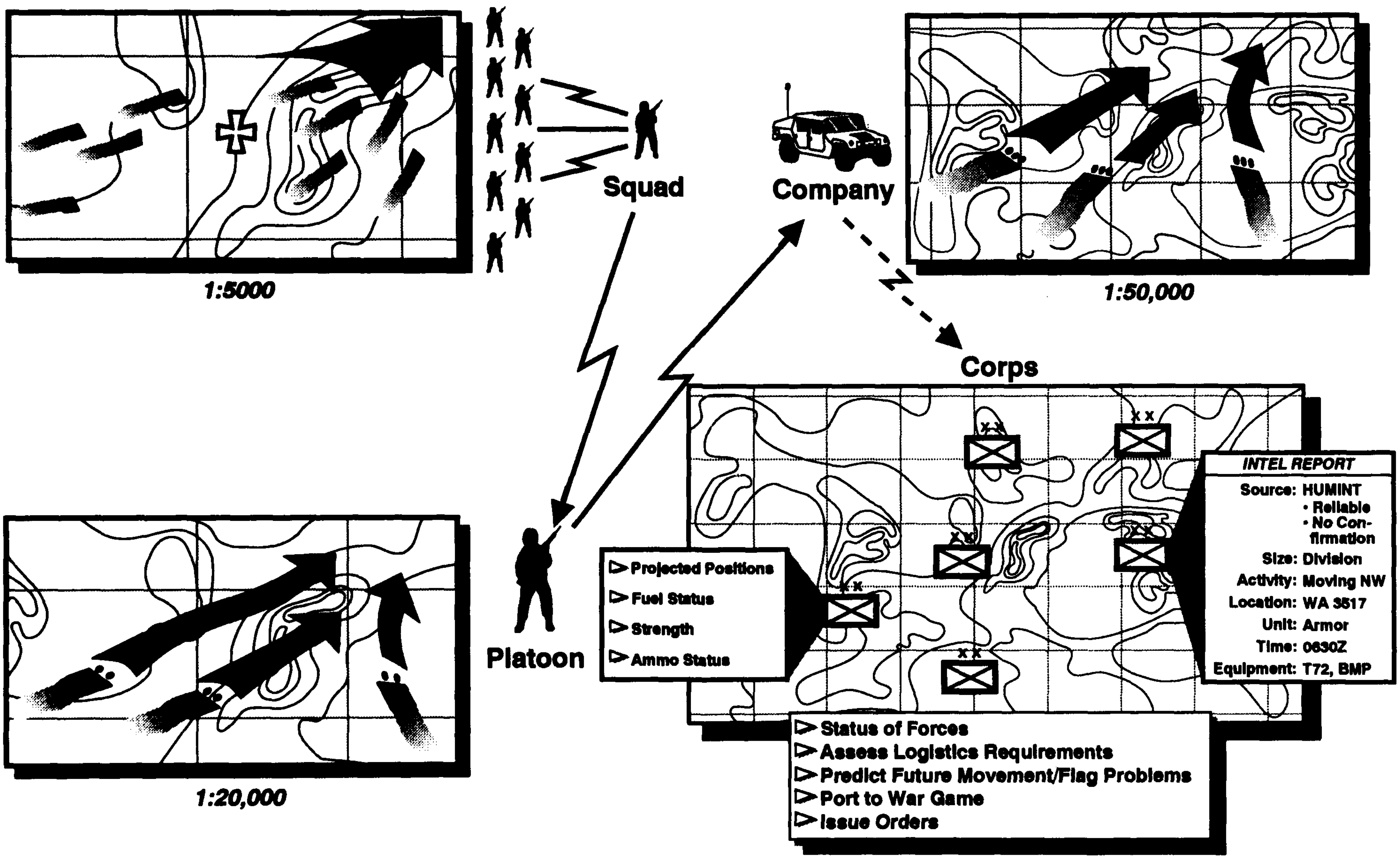
This chart shows a concept for addressing increased timeliness, through-put, and connectivity. Depicted are the principal existing Army communication systems at various levels of command. These systems have various degrees of connectivity; some connections are automated and some are manual. In addition, SINCGARS systems, though compatible, are formed into networks which require gateways in order to connect with one another. This complex structure of interconnections can result in significant delays in passing information up and down the chain of command.

The overlay shows an adjunct communications pipeline which connects all levels and horizontal networks. This system will not replace any existing systems, but will supplement their capabilities to provide improved timeliness and throughput. In addition, because it is connected to individual troops and vehicles at the bottom end, it can serve to pass position and status data from friendly units upward, and to pass intelligence and command data downward. This can then be aggregated into unified, distributed databases (shows as nodes) at each command level. These are discussed further on the next two charts.

ADVANCED LAND SYSTEMS

DISTRIBUTED GRAPHIC DATA BASES



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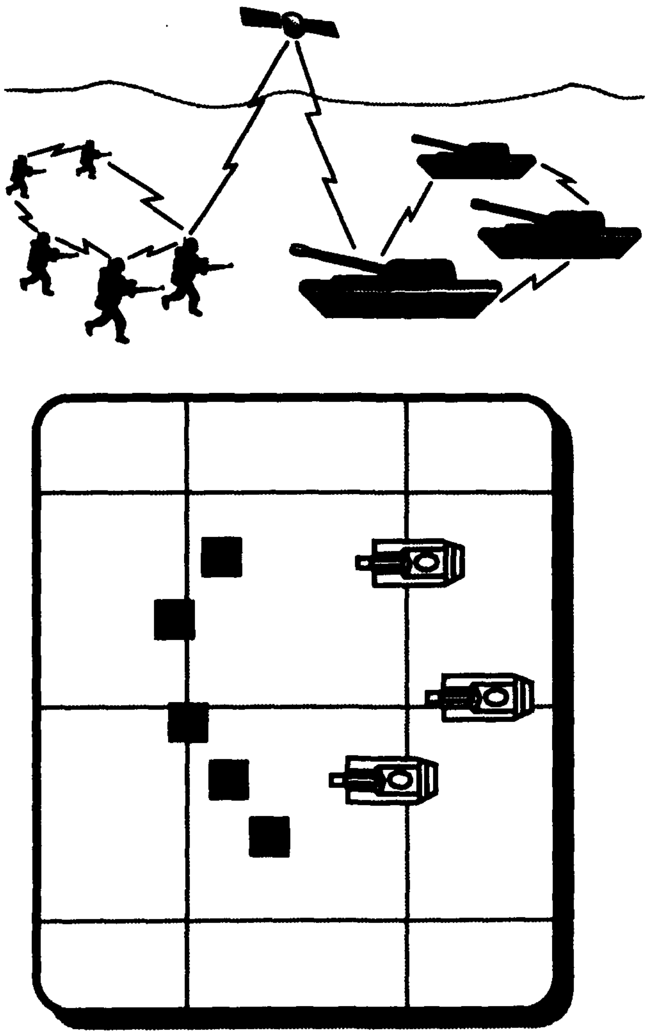
This chart depicts the (notional) data aggregation and interaction process. Each level of command would have access to its own position and status information, as well as any information passed from above. Any commander could see all levels below him, and could grant subordinates access to his map. Maps would contain varying types of information including movement indicators and command information. Lower level maps would be simpler and less capable. Higher level maps would have increasing capabilities which would culminate in a true battle management capability.

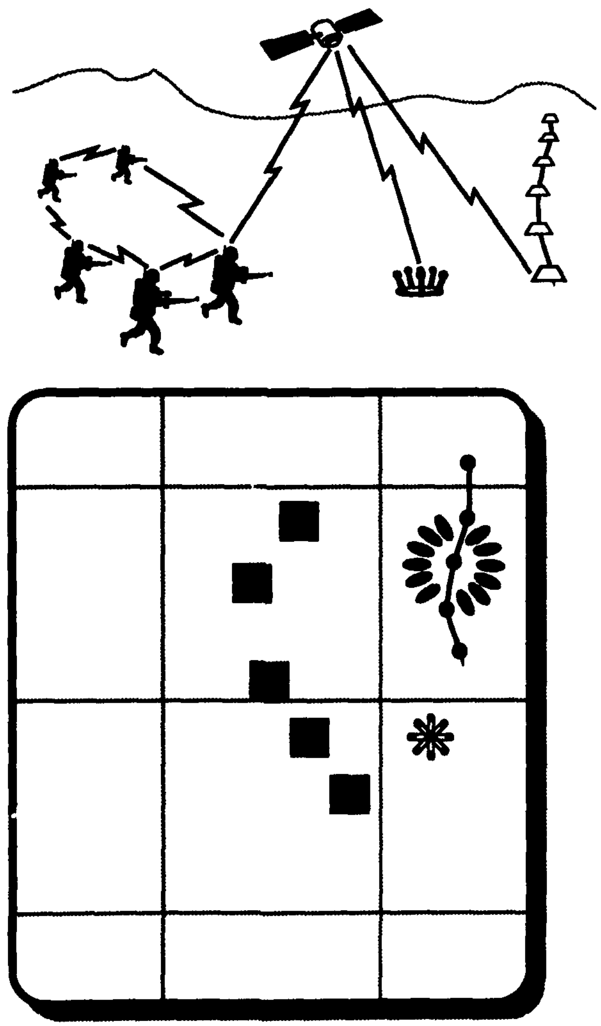
Command level maps would have capabilities such as those shown at the bottom right. Units could be scrutinized (such as the unknown enemy unit at the right) to obtain additional status information. For friendly units, logistics needs could be assessed and projected to establish resupply points. Movements could be projected ahead based on terrain trafficability and fuel availability, and wargames could be played from a variety of possible positions to help establish likely outcomes. The system could also assist in the formatting, routing, and issuance of any resulting orders.

ADVANCED LAND SYSTEMS
SOLDIER'S PERSONAL COMMUNICATIONS SYSTEMS

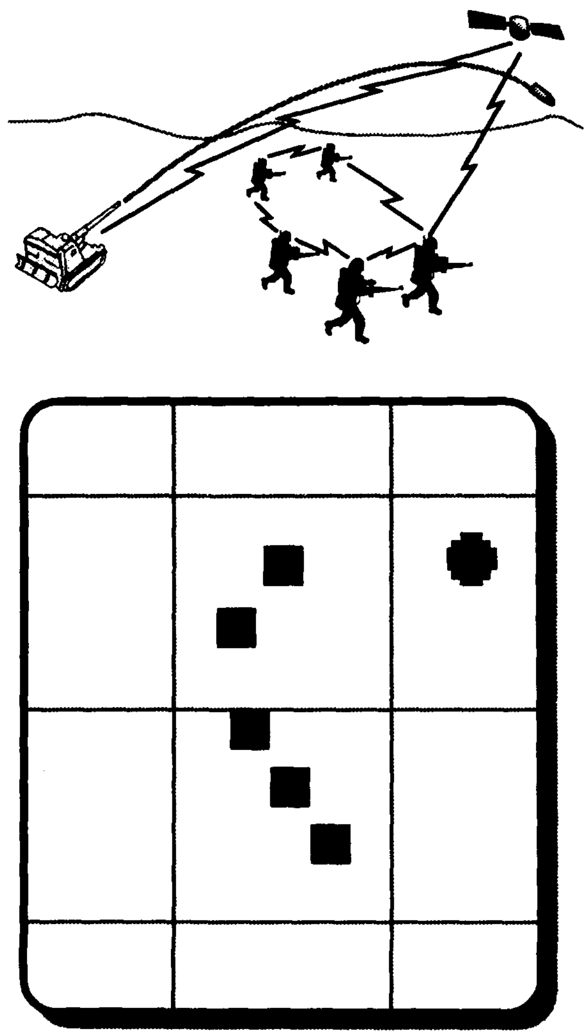
Position/Location Reporting



Virtual Sensing



Virtual Weapon



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The battle management concept can be extended to the lowest levels if an appropriate communication device can be given to individual soldiers. This device might be similar to those being developed commercially under the general name of Personal Communication Systems if appropriate encryption and electronic countermeasure hardening can be added. In conjunction with a small wrist- or head-mounted display and a land navigation system (such as Global Positioning System), this system would allow soldiers to communicate with one another and, via a land- or space-based switching system, with adjacent units or vehicles as shown in the left frame. Each unit so equipped would be capable of communicating voice and data including position/status information and still frame video. This would allow a squad leader to coordinate movements of squad members outside of visual range via voice, alphanumeric menus, or graphics-based commands.

Detection of enemy forces can be assisted through the use of unattended ground sensors employing the same communication system as the soldier as shown in the middle frame. Examples of sensor types include magnetic line arrays for detection of metallic objects (such as vehicles or, at shorter ranges, rifles and radios), acoustic arrays for detection, tracking, and identification of noisy objects (such as motors), and possibly others. As soldiers pass into a zone of influence for each sensor, a processor on the sensor would report the sensor's position and its recent history of detections. This information would be displayed graphically and would be used to cue further observation via binoculars, infrared imagers, or other means.

Once hostile troops have been detected and verified, their position can be designated on the electronic map and reported to an automated or semi-automated weapon, such as a 155 mm howitzer, causing it to load and aim appropriately as depicted in the right frame. Assuming that supporting doctrine has been formulated, the soldier can, in effect, pull the trigger of the howitzer and deliver rapid-response, major caliber weapon fire on to the target. This concept is sometimes called a "virtual weapon".

ADVANCED LAND SYSTEMS

BATTLE MANAGEMENT: APPROACH

▷ ***Phase 0: Concept Refinement***

- **Obtain user and technology input**

▷ ***Phase 1: Studies and Simulations***

- **Collection – appropriate sensors, information sources**
- **Synthesis – electronic displays, data qualifications (purging, data management), speech interpretation/translation**
- **Response – order generation assistance**
- **Communications – use/adaptation of commercial communications, novel communication systems**

Leads to selection of baseline technologies and concepts

▷ ***Phase 2: Testbed Development***

- **Allow users to employ, critique the system**

1276-5-25-93-16

The approach to defining the battle management program is described here. The assumptions and examples shown previously will be briefed to potential users and suppliers to synthesize the goals and potential solutions for the effort. These will then be refined through studies and simulations to assess any technical concerns and to determine their military value. These simulations become increasingly detailed, and will evolve toward hardware in the loop simulations.

Once workable, useful solutions have been determined, functional testbeds will be assembled for use by soldiers in field exercises. Feedback from these exercises will be used to determine the future direction of the program.

SUMMARY

Advanced Land Systems **is changing to meet the changed world situation. Key trends include:**

Forward Basing	Rapid Deployability
Favorable Exchange Ratios	Minimal Casualties
Cost Effectiveness	Budget Driven Choices
Military R&D	Dual-Use, Spin-On

1276-5-25-93-15

We have described two visions for programs in Advanced Land Systems. Both of these have been formulated in response to the world situation as we see it today. However, further change is likely and many additional problems remain. Shown here are several trends which we believe will continue into the future. In general, the US military will be smaller both in manpower and in budget, and will be forced to be flexible and agile, and to leverage technology developments elsewhere for their use. Affordability will be key to all acquisitions.

Advanced Land Systems is actively seeking high payoff technologies and concepts which address current and future needs. Suggestions may be addressed to:

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3701 N. Fairfax Drive
Arlington, VA 22203
(703) 696-2320

V-C MARITIME SYSTEMS

MR. CHARLES E. STUART

Maritime Systems Technologies Office

ARPA Symposium

Mr. Charles E. Stuart

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3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

June 8, 1993

MEMORANDUM FOR MSTO - STUART

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

Reference is made to the following material submitted for clearance for open publication:

MSTO "A VISION OF THE MARITIME FUTURE"

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G. T. Winn
Technical Information Officer

Attachments

Maritime Systems Technology Office

A Vision Of The Maritime Future

Ocean & Maritime Issues

The Ocean & National Security

Navy Requirements & MSTO Programs

TRP & Dual Use Opportunities

MSTO-U-1119-3/18/93 AS OF 3/27/93

Good afternoon. Todays discussion will focus on MSTO's vision of the future use of the oceans. I would like to discuss the importance of the ocean with respect to its abundant resources, transportation on it, and management of the environment. I will also discuss the ocean's relationship to National Security, our successes in MSTO, and our vision of some things that could be. I will present only a small portion of a futurists' vision. I encourage you to send me your ideas.

If you could sweep away the clouds and view the earth at night from the heavens, it would look spectacular. But if you look close, you will see the concentration of people living near the ocean. In the US alone, over 60% of the US population will live with-in 200 miles of the sea in the year 2010.

Yet what do we know about the ocean. The human eye has seen less that one-tenth of one percent of the ocean floor. Some charts our ship's captains use have data on them that date back to last century, measured with rope and weights. The surface of Venus or Mars are better mapped than the ocean.

We keep getting bits of information that should make us turn from the heavens to the earth.

Deep Ocean Hydrothermal Vents

- **10,000 - 16,000 Feet Deep**
- **300° C**
- **Toxic and Radioactive Elements Ejected**
- **Chemosynthetic Ecosystem**

Unclassified Photo of
Hyrdothermal Vents

MSTO-U-1163-5/27/93 AS OF 5/27/93

A recent discovery in the ocean has turned our thoughts of life on Earth upside down. The discovery of life along-side deep ocean hydrothermal vents meant that a long accepted key to life was not so key after all. That key was photosynthesis.

Life can exist and multiply in radically different environments, deep within the oceans, without sunlight. At these depths a chemosynthetic ecosystem thrives with clams the size of dinner plates, shrimps, crabs, tube-worms, and bacteria. All in a toxic environment.

What other information is under the sea? What is preventing us from using the full resources of the ocean?

Ocean Facts (Transportation)

Over 96% of Trade Among Countries is Carried by Ships

- **Desert Storm Deliveries:**
  - **3.5 Million s/Tons of Dry Cargo**
  - **6.2 Million s/Tons of Fuel**

MSTO-U-1117-5/17/93

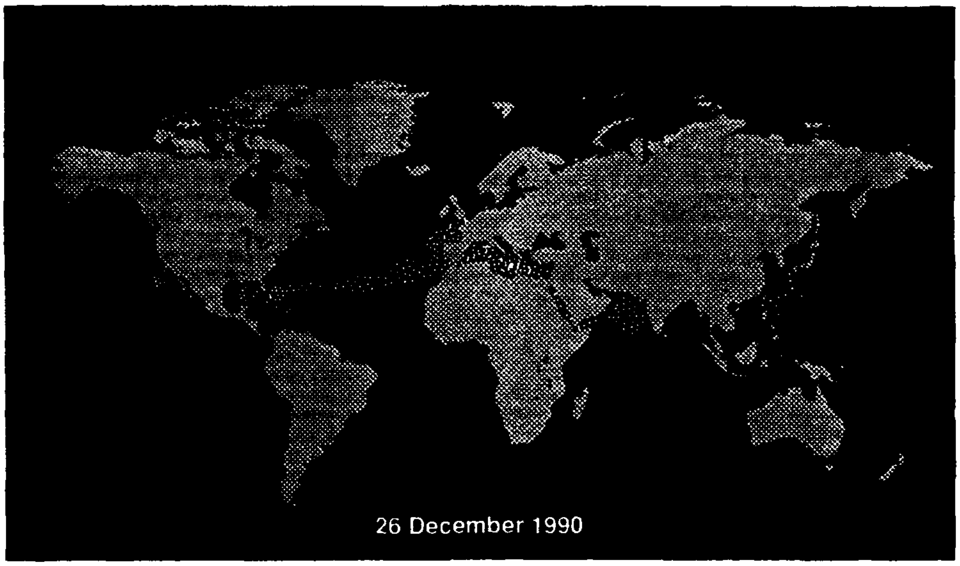
AS OF 5/21/93

The ocean is a formidable place. Those of you who have spent time at sea know the perils a storm can cause. We are continually reminded of the power of the sea each year when a hurricane comes ashore.

Even with these threats, 96% of commerce between countries is conducted over the sea. Why? Because the least expensive way to move great volumes of cargo is by the ocean. However, our infrastructure of port facilities and rail lines are not advancing with technology, we let the world send the cargo around us, rather than through us. Desert storm gave us great insight into the weakness of our infrastructure to move cargo fast and efficient. Equipment and supplies stacked up for miles outside of Charleston on the way to the Persian Gulf.

A Snapshot In Time — The Steel Bridge

MSC

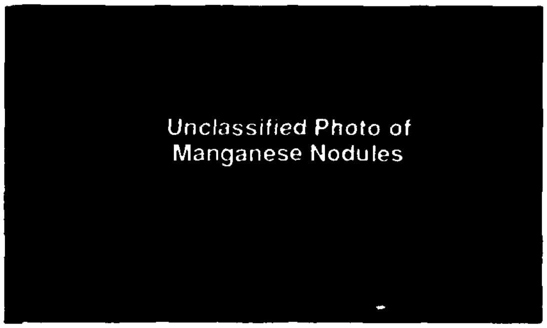


MSTO-U-1157-5/23/93 AS OF 5/04/93

Desert Storm did show the strength of sea transport. Over 9 million tons were shipped over the ocean. A massive undertaking. If you consider only the first two Maritime Prepositioning Ship Squadrons that delivered material in the first days, you would have needed a C-5 cargo transport taking off every 7 minutes for 9 days. On December 26, 1990, the oceans would have looked like this. If you had spaced the ships evenly across the ocean and had flown the route over them, you would have flown over a ship once every 50 miles. Yet, with all this need for ocean transport, we build no commercial transport vessels in this country.

Ocean Facts (Resources)

- **There Are About 1.5 Trillion Tons of Manganese (Mn/Ni) Nodules on the Pacific Ocean Floor**



- **Every Cubic Mile of Seawater Holds Over 150 Million Tons of Minerals**
- **Total Annual Commercial Harvest From the Seas Exceeds 85 Million Metric Tons**

MSTO-U-1114-5/17/93 AS OF 5/21/93

We import all of the strategic minerals this country requires. Yet there is manganese lying on the ocean floor in the form of nodules ready to be plucked. 1.5 Trillion Tons of it to be exact. If you mined enough of these to supply the US with one years' supply of nickel, you would also get 200 times the requirement for Cobalt, 300 times the Manganese, and significant amounts of titanium, vanadium, and zirconium.

Maritime . . . MSTO

. . . of Countries and People Dealing in Matters of Commerce and Navigation on the High Seas, Inland Lakes and Rivers, . . .

Unclassified Photo of Woods Hole, MA Harbor

Maritime Missions for National Security

- **Interdiction & Protection of Land & Sea Lines of Communication**
- **Power Projection**
- **Policing**
- **Regional Security**
- **Humanitarian Assistance**
- **Exploration, Commerce, Presence**

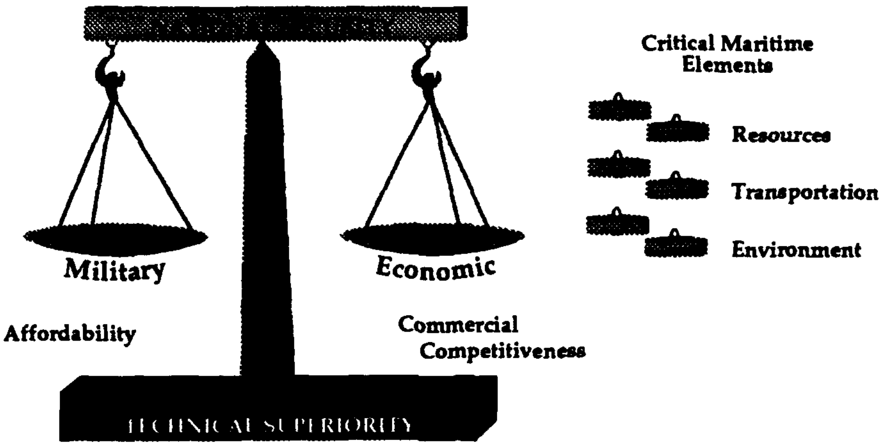
MSTO-U-1120-5/18/93 AS OF 5/27/93

Our national maritime interests should not be viewed only in historical or traditional aspects, but in relationship to national security. Sea power is the sum total of our nation's involvement in the ocean.

Exclusive Economic Zones

The Exclusive Economic Zone legislation signed by President Regan in 1983 gives the US the largest territorial waters of any nation on earth. It effectively doubles the size of the US. Over 2.3 million square miles, 85% of which are in the Pacific. It has been estimated that over 15% of the world's living resources are in the EEZ.

The National Security Equation



National Security = Military Security + Economic Security

But national security is more than just sea power. It is a balanced equation of military and economic security built on a foundation of technological superiority. This is how we should view the use of the ocean - with its resources, transportation opportunities, and wise management of the environment as critical elements of the national security equation. Military security will be affected by today's procurement constraints in the post cold war era and demand affordable ships and components. Economic security will be affected by our nation's ability to maintain and increase our commercial competitiveness.

MSTO-U-1153-3/31/93 AS OF 3/23/93

We won. The Soviet threat is gone. As a result there is no longer a threat **capable of blue sea dominance. Sea control belongs to the US.**

Requirements — Technology Response

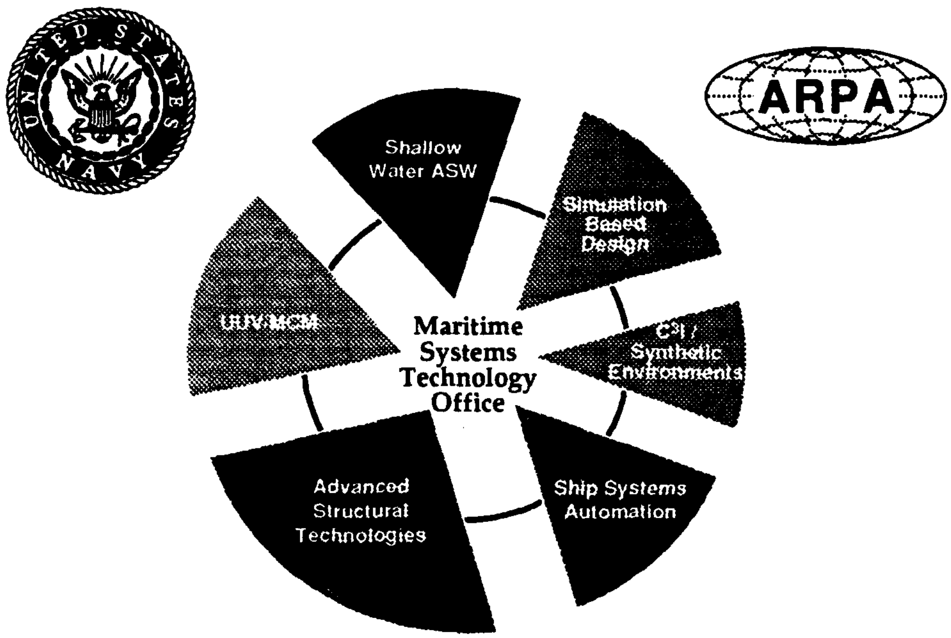
Requirements
- Political/Economic Security
- From the Sea

Affordability
Aquisition Reform

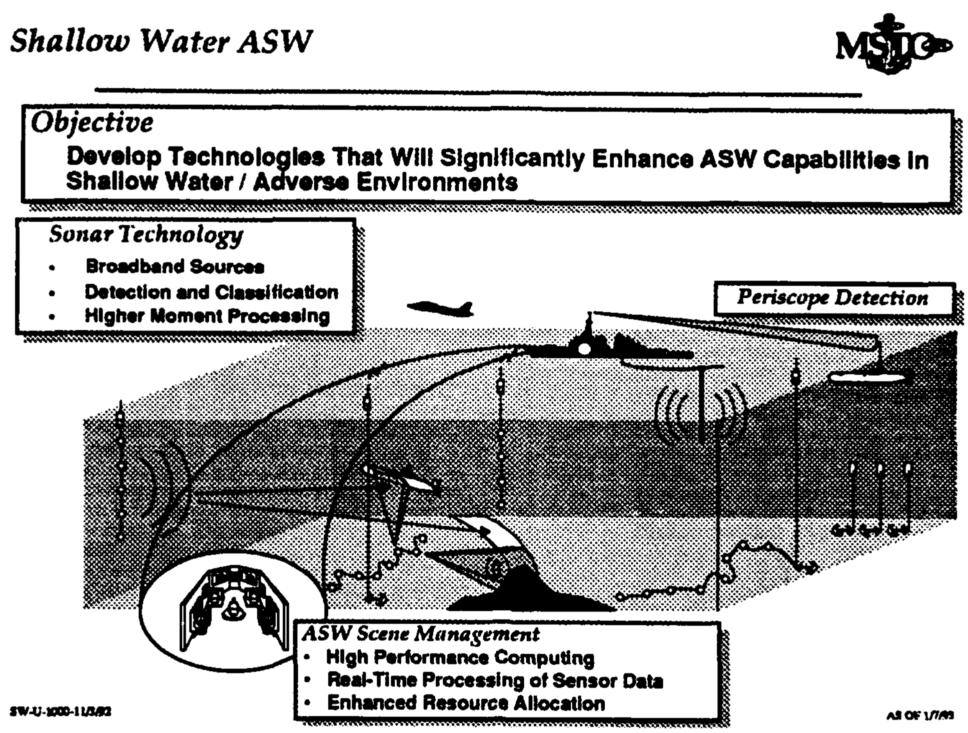
Enabling Technologies
- Stealth/Counterstealth
- Automation
- Energy Systems/Propulsion
- Materials/Structures
- Information & Signal Processing
- Design/Manufacturing
- Ship/Shipbuilding Technologies

MSTO ARPA

Top level Military requirements are defined by the Secretary of Defense. The Navy, following these requirements issued its "From the Sea" doctrine, which I'm sure you are all familiar with. The result is a focus on littoral warfare, an area which although not completely ignored in the past, poses a set of challenges that the technical community is now trying to come to grips with. Affordability and acquisition reform are important considerations when developing programs to meet these new littoral requirements. MSTO analyzes this synthesis of requirements and focuses on enabling technologies that cut across broad areas and then shapes them into distinct programs, which addresses the challenges of this littoral environment.



The Maritime Systems Technology Office was formed by ARPA approximately a year ago to pursue a wide range of technologies related to the broader issues inherent in maritime systems. The six programs presently underway are depicted in this pie chart.



This program has as its objective the development of technologies that will significantly enhance ASW capabilities in shallow water/adverse environments.

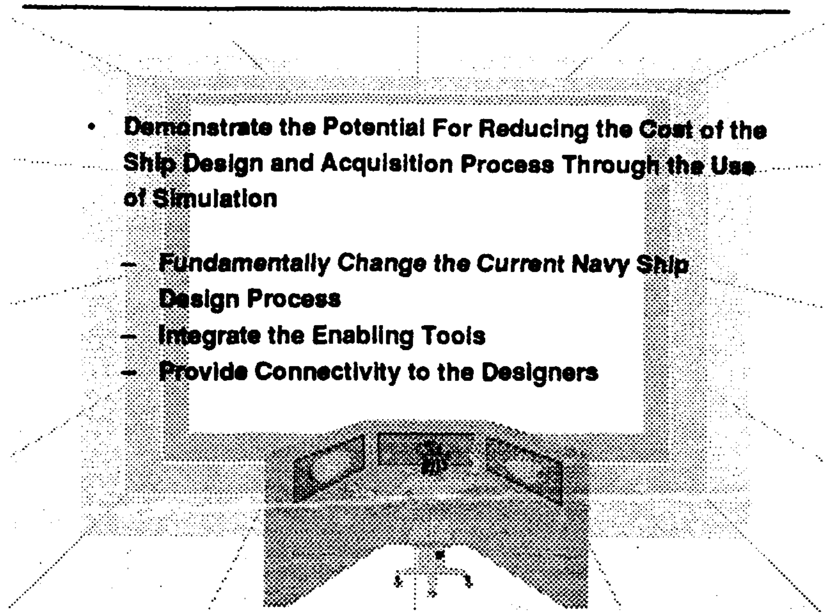
The program is focused in three areas:

• Sonar technologies, which includes broadband sources, detection and classification and poly spectra signal processing

• ASW scene management, which includes the application of high performance computing to real time processing of sensor data and enhanced resource allocation

• Periscope detection will demonstrate reliable detection capability in adverse sea states with low false alarm rates.

Simulation-Based Design . . . Virtual Prototyping
Objective



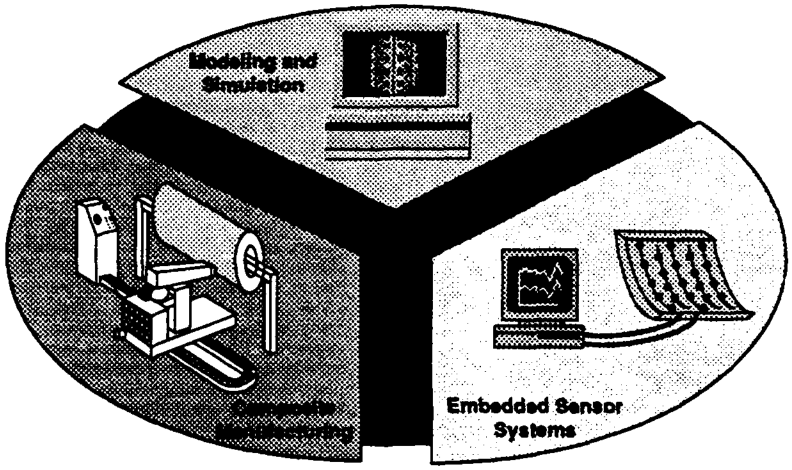
SBD-U-0056-3/23/93 AS OF 3/23/93

This program has as its objective the demonstration of the potential for reducing the cost of the ship design and acquisition process through the use of simulation.

The program will focus on fundamentally changing the current Navy ship design process, by integrating all enabling tools and by providing connectivity to the designers. Virtual prototyping will be used to produce designs that are optimized at the system level, vice the traditional method of design where optimized subsystems are integrated into a whole.

Advanced Structural Technologies
Materials

Provide Designers with Affordable, Efficient, Safe Composite Structures



STP-U-M-0525-10/19/92

AS OF 3/2/93

This program has as its objective the development of active structural control technologies and advanced materials, to provide far term solutions to ship affordability and capability.

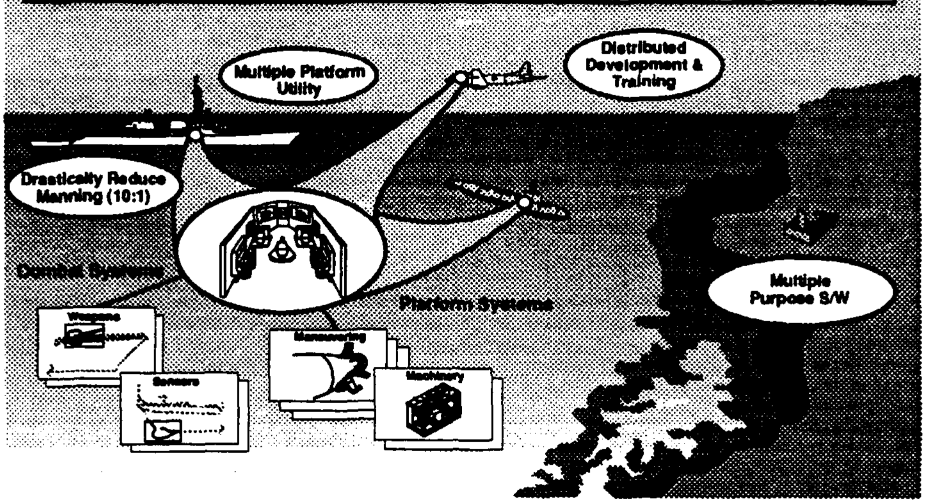
The program will focus in advanced materials on the development of affordable efficient safe composite structures to give ship designers alternative materials to consider during the design process.

The structural control portion of the program will focus on developing means to reduce target strength and radiated noise, plus apply this fundamental knowledge to actively control mechanical vibration in structures of arbitrary size and complexity, such as in precision machining and turbine vibration control.

Ship Systems Automation

Objective

Demonstrate Automation Technologies That Will Drastically Reduce Manning and Acquisition Costs



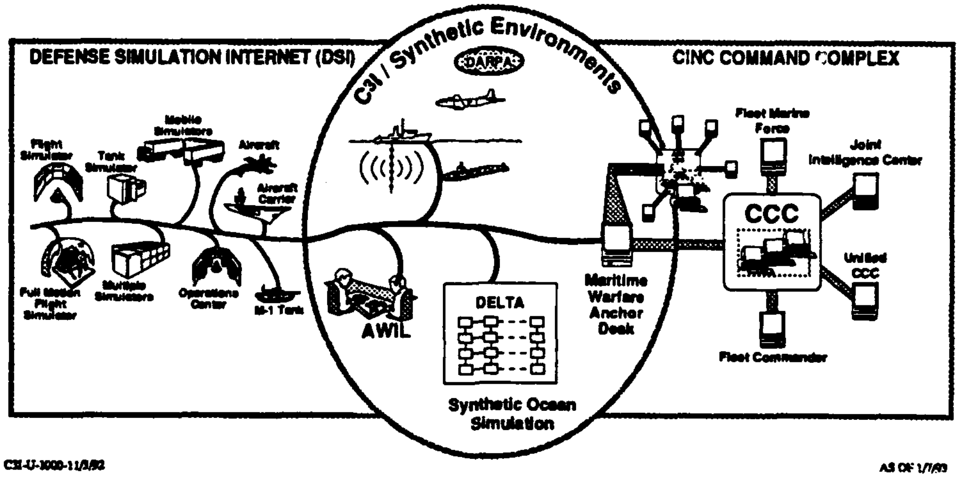
SSA-U-0041-2/3/93 AS OF 4/16/93

This program has as its objective the development and demonstration of technologies that will reduce manning and acquisition costs, while improving performance.

This program complements the Simulation Based Design program, by developing automation technologies and distributed virtual environments to promote integrated product and process development. The systems being pursued include both combat systems and platform systems.

Objective

Develop CINC Level Battle Management Decision Aids and the Synthetic Ocean Environment to Support DoD Expeditionary Forces. Operating *from the Sea.*



C3I-U-1000-11/3/92

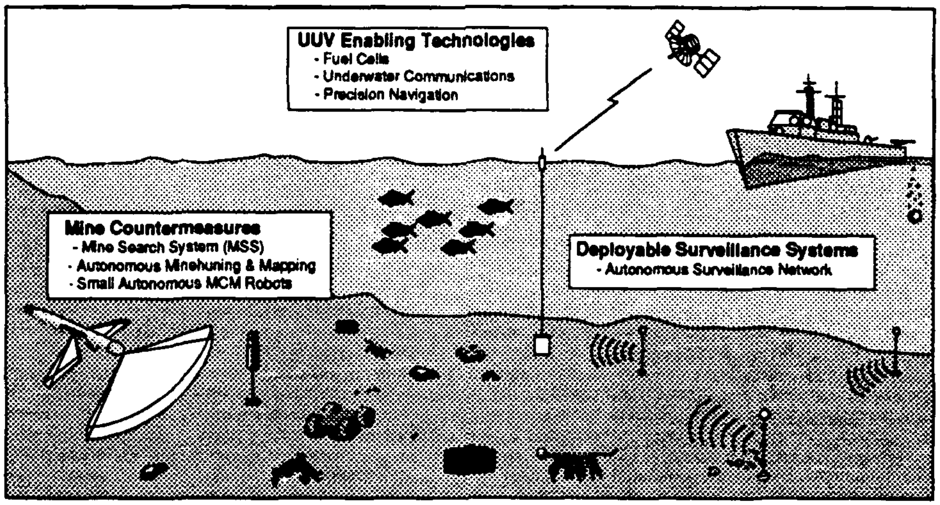
AS OF 1/7/93

This program has as its objective the development of Fleet command level battle management decision aids and a synthetic ocean environment to support expeditionary forces operating from the sea.

The program will develop a maritime warfare anchor desk that will permit real time planning, analysis of war plans and improved resource allocation. Additionally, the program will develop a high fidelity acoustic ocean environment model, that will contribute to improved readiness and training. This same model will lead to improved acquisition, since emerging systems performance can be analyzed using this synthetic environment.

Objective

Develop *Fully Autonomcus* Maritime Systems

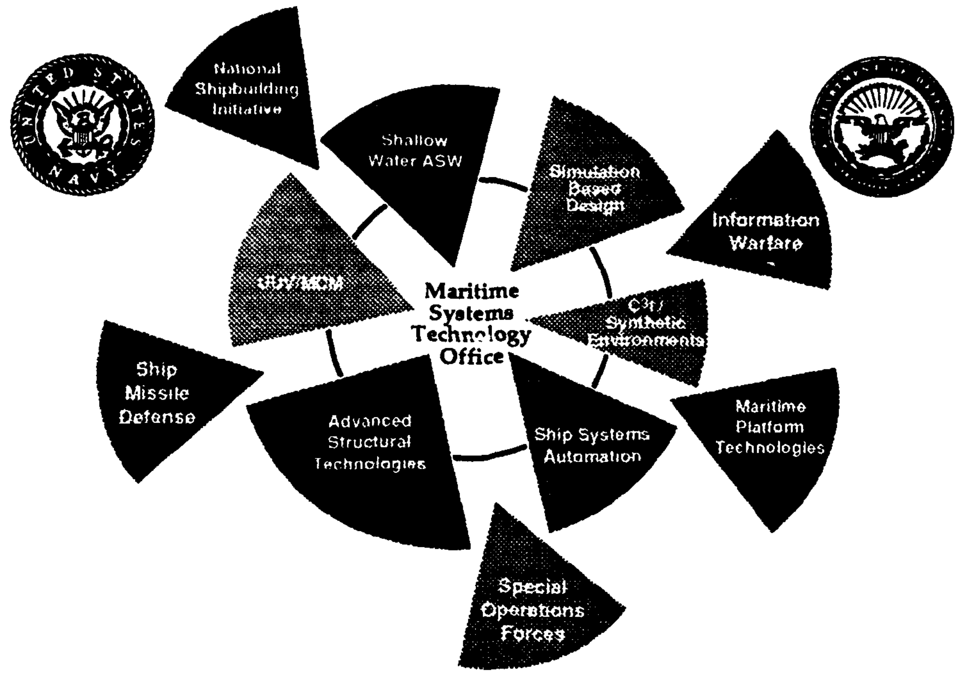


The Unmanned Undersea Vehicles/Mine Countermeasures Program has as its objective the development of fully autonomous systems. The program is focused in three areas:

- **Unmanned undersea vehicle enabling technologies, which includes fuel cells, underwater communications and precision navigation**

- **Deployable surveillance systems, which includes an autonomous surveillance network and an advanced technology acoustic array**

- **Mine countermeasures, which includes the mine search system, autonomous minehunting and mapping and shallow water mine countermeasures.**



MSTO-U-1159-3/25/93

AS OF 5/27/93

In response to the changing world, and to make full use of the TRP opportunities, we are formulating new programs to match emerging requirements. Some of these programs are further along in their implementation than others. Some are still being developed. This vugraph shows the MSTO organization we have already discussed, with an overlay of the new programs. I'd like to discuss some of the highlights.

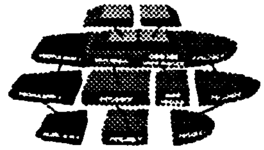
Maritime Platform Technologies

Objective

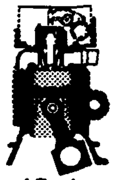
Develop Maritime Systems and Associated High Value Components That Are Affordable, Modular, Scalable and Rapidly Deployable

Large Modular Systems

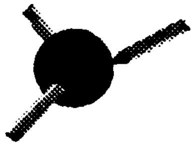
Constellations of Small Modular Systems



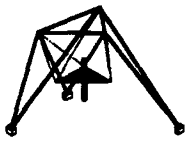
High Value Components



Advanced Engines, Motors, & Generators



Advanced Structures & Joinery



Automated Assembly & Operations

MPT-U-1000-3/22/93

AS OF 4/22/93

The MPT program is divided into three main areas: families of large modular systems, families of small modular systems, and high value components. The focus of the Maritime Platform Technologies (MPT) program will be on modular components that can be reconfigured into multiple mission-specific configurations. The concept is an "open systems" approach to platform systems technologies.

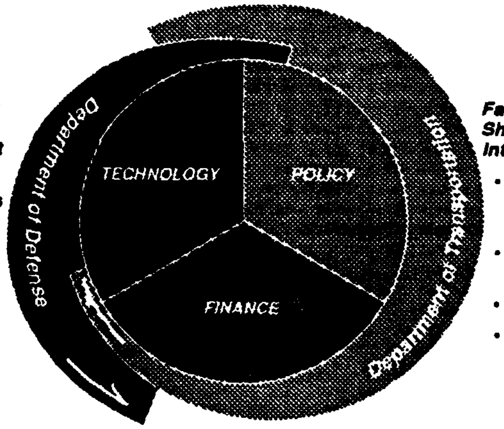
What is the Alternative Approach

Joint Program DoD/DoT

ARPA

Technology Development for Shipbuilding Productivity Improvement

- **Focussed Development Projects**
- **Maritime Technology Centers**
- **Ship & Shipbuilding Technologies**



MARAD

Facilitate U.S. Shipbuilding for International Sales

- **Loan Guarantees for Shipyard Modernization**
- **Performance Bond Underwriting**
- **Title 11 for Export**
- **Marketing Analysis**

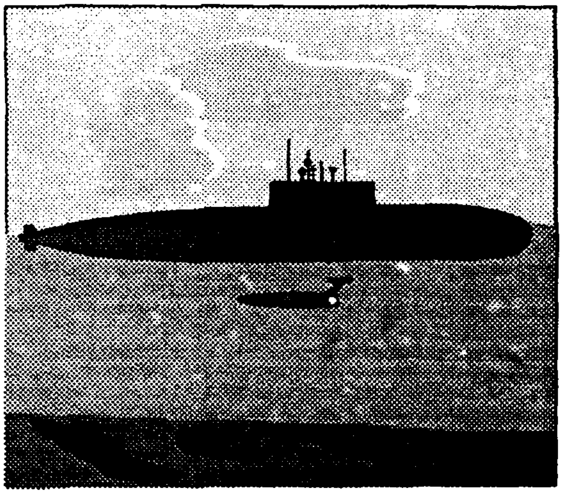
Creating a Self-Sustained Industrial Base

NSI-U-0164-4/28/93 AS OF 4/28/93

The House Armed Services Committee asked ARPA to formulate a program to revitalize the US Shipbuilding industry. The National Shipbuilding Initiative is our vision of a program to fund innovative, near-term ship design and construction projects creating a world class shipbuilding industry in the US. It is to be a joint effort with the Maritime Adminstration.

The objective is to encourage and support the development of innovative, commercial ship design concepts. The concepts will integrate specific markets with new, more efficient production processes to the point that competitive construction of the ships can start within 2 to 3 years. ARPA will also begin to establish and integrate a national infrastructure of regional maritime technology centers that will assist industry in achieving and maintaining a world leadership position in commercial ship design and construction.

- **All Weather Insertion Vehicle (Glide, Suface Transit, Submerge)**
- **UUV for Harbor Surveillance or Device Attachment**
- **Bistatic Radar Using Commercial Broadcast Signal**
- **Night Vision Goggles Detector**
- **MEMS Based Multi-Function Wrist Watch**
- **EMP Generator**
- **Stealth Suit**

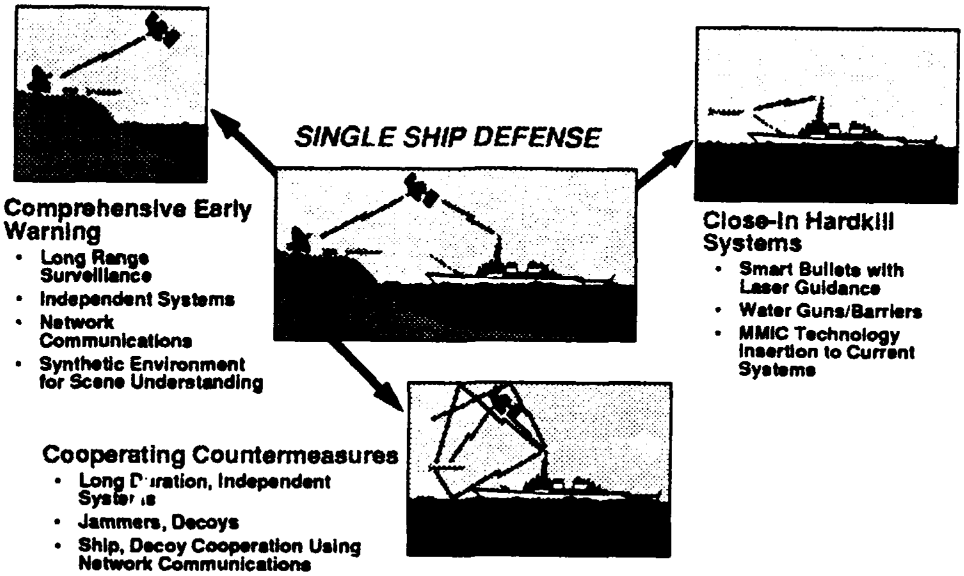


Special Warfare Forces are currently tasked by our Nation to perform and enormously wide range of mission, the unifying principles of which are: do whatever needs to be done, don't get caught, and do not fail.

Future projects include an all weather delivery vehicle which will enable response to crises near any shore anywhere on the globe within 24 hours. The vehicle will be air dropped from low altitudes to the sea in any weather. It would then conduct a high speed surface transit and a submerged low speed final run-in to the shore.

Other projects involve the prevention of thermal detection of personnel, UUVs for reconnaissance, stealthy weapons, passive target detection, and virtual reality planning and training.

Anti-Ship Missile Defense



MSTO-U-1162-5/27/93

AS OV 5/27/93

Anti-Ship Missle Defense in Littoral Warfare is a tough problem. Destroying the incoming missiles is very difficult as the physics of the problem is unfavorable. Just trying harder with the same approaches won't work -- a fundamentally new concept is needed.

The solution should be based on a single ship defense approach relying on comprehensive early warning, corrperating countermeasures to defeat missile lock-on, and close -in hardkill systems.

The enabling technologies will include HF surface radar, MMIC, long-duration independent systems, network communications, synthetic environment for scene understanding, smart bullets, and water guns.

Things That Could Be

Resources

Access to Food, Energy & Mineral Resources

Transportation

Rapid, Efficient, Safe Movement of Commercial & Military Cargos

Environment

Economic & Military Utilization of Maritime Environment

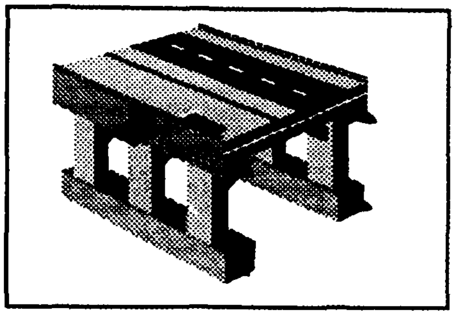
MSTO-U-1124-5/18/93 AS OF 5/27/93

The programs that I have briefly discussed were evolved from the traditional DOD requirements process and passed through the ARPA filter, resulting in programs that hopefully would be of value to MSTO's customer the NAVY.

However, National Security as you recall, balanced military security and economic security through elements of resources, transportation, and environment. Where do the requirements for economic security come from? This is a much broader and poorly defined area. In June 1992 the National Science Foundation and the National Oceanic and Atmospheric Administration held a meeting to develop a strategic plan for the use and management of our Nation's ocean resources. I used their report "U.S. Ocean Resources 2000" as an ecomomic requirement because its broad scope and vision. If we use "Resources 2000" as a backdrop and let our minds dream of the future, we could envision spectacular things. Unmanned robots mining the deep ocean floor; rapid cargo movement across oceans in safe, efficient ships; perhaps a novel idea like a federal express of cargo awaits us. Stealthy ships capable of high speeds and submergence for operations in littoral waters. Lobster-like robots for mine hunting.

Large, Stable Structures to Provide a Platform for Multiple At-Sea Uses

Military



Commercial

Unclassified Photo of Oil Rig

MSTO-U-1127-5/18/93

AS OF 5/27/93

The platforms have tremendous dual use potential. Militarily, they can be use to preposition forces, act as primary bases for littoral warfare, or support offshore missile or satellite lauches.

Commercially, the list of uses is long. Futurists envision large floating ocean cities that take advantage of all the ocean's resources. Other ideas include commercial airports, fish processing plants and aquaculture, as well as industrial processing of many kinds. With a focus at the right technologies in materials, connectors and joinery, simulaiton based design, and others these large platforms could be built economically. That is what has stopped their development in the past.

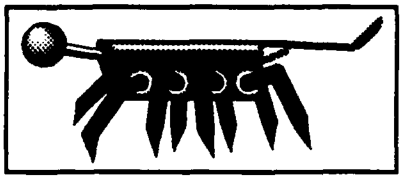
Remote Access

Technology

Micro-Electro-Mechanical Systems

- **— Sensors**
- **— Acutators**
- **— Processors**

Unclassified Photo of
Micro-Wobble Motor



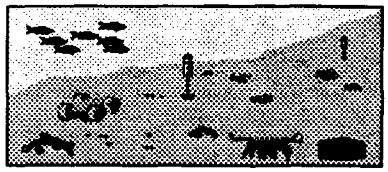
Systems

Small Robots

- **— Small, Inexpensive Sensors**
- **— Simple Control System**
- **— Group Behavior**

Applications

- **Mine Countermeasures**
- **Sea Floor Sensors**
- **Mining Support**
- **Environmental Monitoring**
- **Surveillance**



AS OF 5/27/93

The development of micro-electro-mechanical systems makes it possible to build small inexpensive robotic devices that would have a number of applications in a maritime environment. For example, MSTO is beginning a project to demonstrate the feasibility of small robots, which would be deployed in large numbers in shallow water and would search for underwater mines. Upon finding a mine, a robot would remain near the mine waiting for a signal to detonate the onboard explosive. Such devices could also proceed onto land for surveillance or the destruction of obstacles.

Commercially, these systems would aid in harvesting the ocean floor in mining operations, act as sensor systems, or go, economically, where it is difficult to place humans.

Future Ships

MSTO

Commercial/Military

- **Highly Automated**
- **Faster**
- **Efficient**
- **Intelligent Cargo Handling & Transfer**
- **Modular Construction**
  - **— Prefabrication of All Major Subsystems & Components**
- **Advanced Propulsion**
- **Unique Hull Forms (SWATH, Semi-Planing, SES)**
- **Non-Polluting**

Unclassified Photo of
Future Ship

Military

- **Stealthy**
  - **— New Materials, Low Observability**
  - **— Submersible**

MSTO-U-1132-3/18/93 AS OF 3/18/93

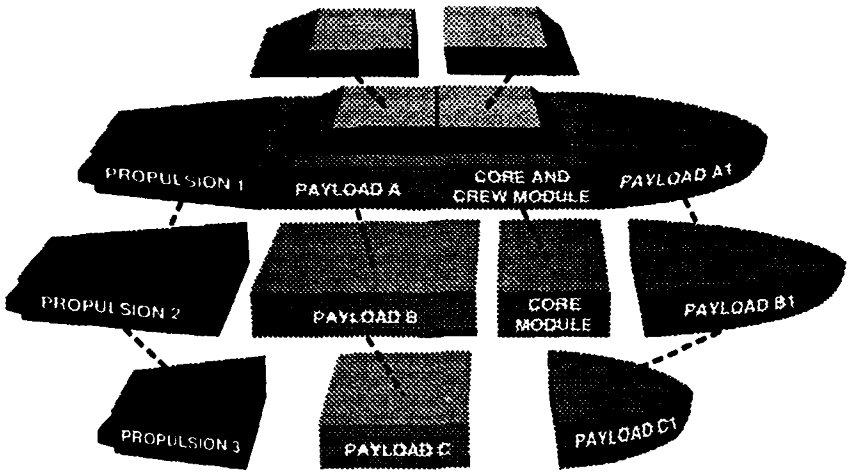
The activities of MSTO quite naturally coalesce at a common point, Ships of the United States at sea continuing our heritage as a Maritime Nation.

Be they commercial or military, ship construction of both categories are now constrained by a common and increasingly important fact, affordability. In both cases, we must find the way to deliver high technology ships at affordable costs or suffer adverse consequences.

On the commercial side and under the auspices of the National Shipbuilding Initiative, we are committed to assisting in the return of our shipbuilding industry to a position of international competitiveness and construction preeminence in the world market. We will leverage our technological energies to effect the production of top quality, environmentally sound ships of superior design at competitive prices in our US yards.

On the military side of the equation, commercial shipbuilding in the context of the National Shipbuilding Initiative should be viewed as a complementary and supportive ally. Until such time as the next cyclical requirement for major Navy ship construction occurs, a robust commercial shipbuilding posture will maintain the nation's shipbuilding base. Anticipated improvements in commercial ship design techniques an construction practices will translate directly into the ability to build Navy ships at lower costs in the future. In addition, ARPA will continue its traditional pursuit of research and developmental advances in such ares as stealth which will allow us to produce highly sophisticated ships which exceed military characteristic requirements and provide to the fleet a clear technological superiority.

Family of Modular, Reconfigurable Craft



Ocean Reconfigurable Craft-Advanced (ORCA)

MPT-U-1021-4/27/93 AS OF 4/27/93

Families of reconfigurable small craft with multi-mission capabilities could be deployed in support of operations such as surveillance, mine warfare, strike warfare, or counter narcotics. The patrol class size vessels would be rapidly deployable by air or ship and rapidly assembled and configured near or in-theater for specific missions.

Intelligent Automated Seaways

Description

- **Assist *Ship Routing and Handling* Through Communications, Navigation, Automation**
- **FAA Approach to Ship Traffic Control**

Benefits

- **Safety of Life at Sea**
- **Improved Routing of Ships to Avoid Collisions and Weather**
- **Reduced Crew Size**
- **Automated Ship Handling in Transit Lanes**

MSTO-U-1149-3/21/93 AS OF 3/21/93

In 19xx, the Atlantic Empress collided with the Aegean Captain off Tobago. It resulted in the loss of 26 lives, loss of the empress, and the most oil ever released to the environment, over 279,000 tons. The sad part is that it took place in broad daylight in clear weather.

With the right technology, perhaps an FAA approach to Ship Traffic Control, these catastrophies could be avoided.

With the focus of MSTO in automation, a major impact could be made in the safety of life at sea. You could envision automated ship handling in transit lanes, reduced crew size, improved routing of ships to avoid collision. They would also avoid weather. In addition automated ships could be use for military sea lift because of the lack of commercial base.

Rapid Intermodal Transport System

Description

- A Total Systems Approach to Cargo Movement
- Integrated Rapid Transfer of Cargo from Ship to Rail to Truck
- Total "Visibility" of Cargo from Origin to Destination
- Federal Express Concept Applied to Cargo Routing

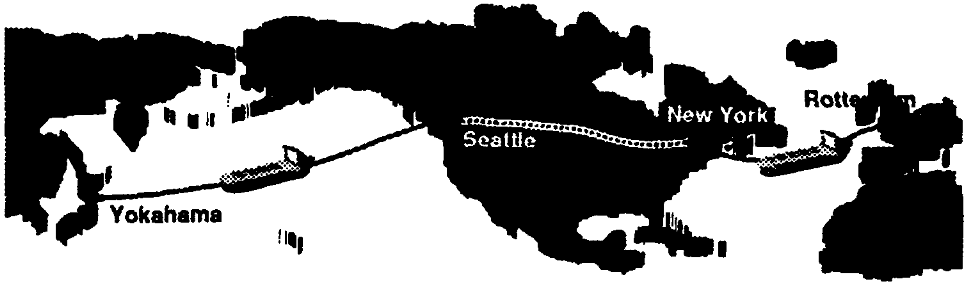
Benefits

- Improved Delivery Times
- Efficient Cargo Movement from Point of Origin to Destination
- Rapid Response to Market Demands
- Significant Fuel Savings
- Fewer Miles Travelled
- Reduced Interstate Truck Traffic
- Extensive Military Benefits
- Improve Rail & Port Infrastructure

MSTO-U-1133-3/18/93 AS OF 3/25/93

Federal Express revolutionized the way letters and packages were shipped and handled. Imagine a total systems approach to cargo movement. An integrated system that allowed a seamless transfer of cargo from ship to rail and truck. Automated and efficient port facilities using robot cranes. Smart cargo that knows its destination and could be tracked from origin to destination.

Rapid Intermodal Transport System
Example: Rotterdam to Yokohama



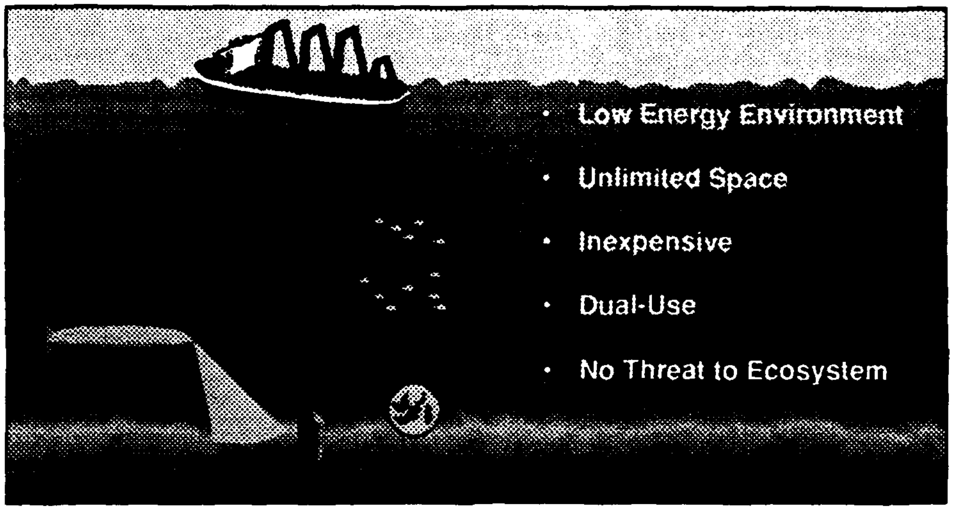
		Distance	Time Today	Time Tomorrow
Via	**Suez Canal and Singapore**	**11,300 mi**	**31 Days**	**25 Days**
Via	**Panama Canal**	**12,000 mi**	**34 Days**	**27 Days**
Via	***U.S. Rapid Intermodal Transport***	***9,900 mi***	***27 Days***	***19 Days***

MSTO-U-1146-3/21/93 AS OV 3/27/93

Today, a large percentage of world shipping, perhaps as high as 70%, bypasses the US. It goes throught the Panama Canal or Suez Canal. If our rail and port infrastructure was revolutionized, we could capture this shipping. It would be shorter in both miles and time. As technology improves ship speeds and train speeds the impact could be tremendous. A typical container ship costs over $50,000 a day to operate. A savings of time means a savings of money. An efficient north-south shipping corridor could alleviate or eliminate interstate truck traffic on I-95.

A revived rail and port system would improve all sea lift operations from both coasts in response to contingencies on all points of the compass.

Deep Ocean Isolation



MSTO-U-1138-5/19/93 AS OF 5/27/93

A major discovery of deep ocean hydrothermal vents was made in 1977. As described by Dr. John Edmond who witnessed the event with Dr. Bob Ballard using the famous ALVIN submarine, vents directly below the Gulf of California under one of the world's most popular salt water sportfishing areas, produce more carcinogenic aromatics than are in Boston Harbor. If this area was on land it would be a major superfund cleanup site. Radioactive elements and toxic materials are naturally injected with no discernible impact beyond their immediate location, due largely to the tremendous pressures of up to 7,000 psi. and abyssal currents that are too small to measure

The abyssal plains at depths of 10 to 16 thousand feet are safely away from these ocean vents. They are devoid of marine life because they lack the food produced by the vents. All this makes it a perfect place to store waste. The challange will be to marry the technologies of large offshore diving programs, large floating platforms, remote underwater vehicles, and underwater sensors to build a deep ocean isolation program.

The Challenges

- Continuous Access to the Ocean Floor
- Rapid Intermodal Transport System and Automated Seaways
- Safe, Economical Disposal of Industrial and Municiple Wastes
- Future Ships?

I have attempted in this short period to show you that the Oceans are of great importance to the country, from both an economic and defense perspective. Additionally, I'd like you to remember that the ocean is largely unknown to the people that live close by yet are effected by it in so many ways.

There are four broad challenges that I see, that if addressed in a systematic way will permit harnessing this vast resource. Prudent management of the oceans is perhaps the greatest challenge.

I have provided you some of my thoughts on directions we might take, but what I need is your ideas on how to make the oceans more accessible toenvironmentally safe activities, that promote economic opportunities for the country.

I look forward to the dialogue.

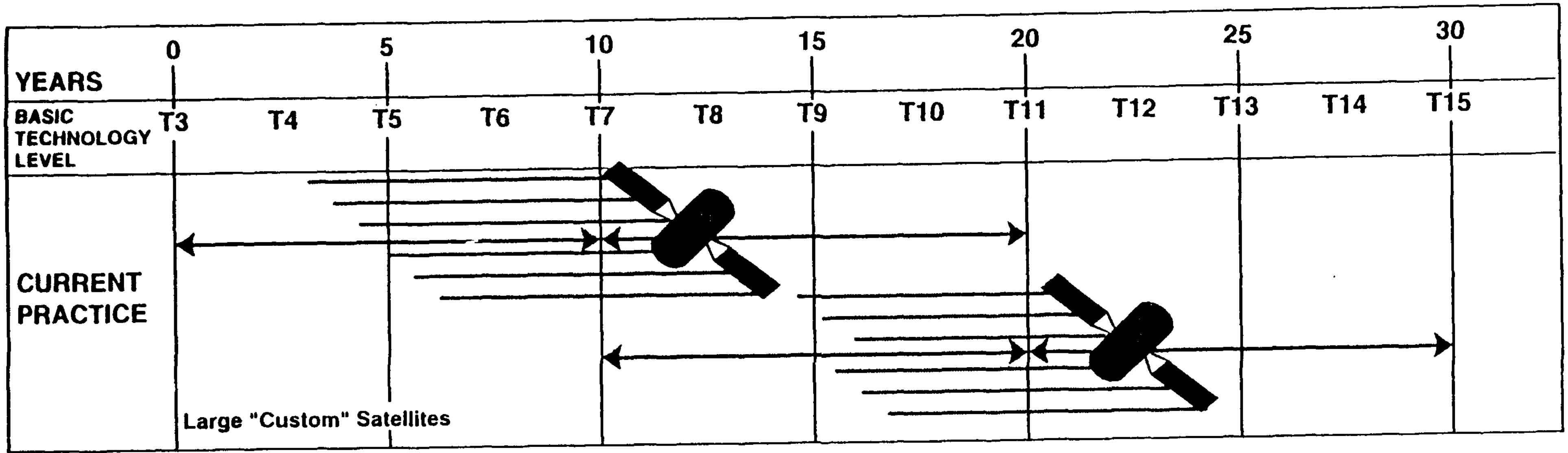
Thank you.

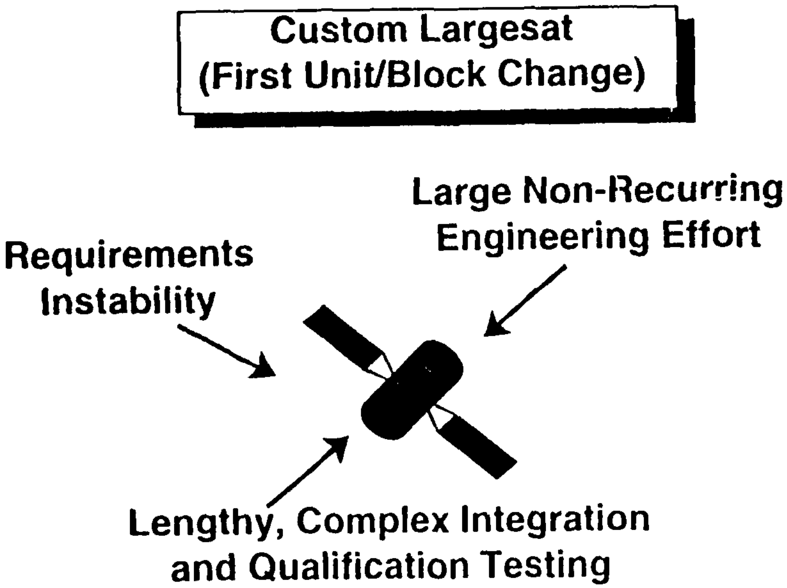
V-D SPACE SYSTEMS

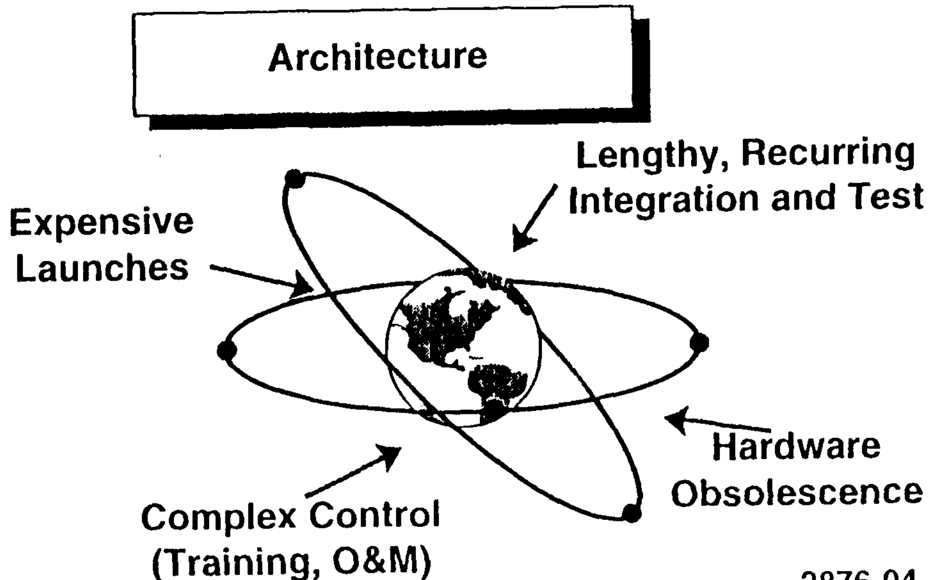
LTCOL LEE F. DEMITRY

CURRENT PRACTICE AND COST DRIVERS SATELLITE/ARCHITECTURE

Advanced Systems Technology Office







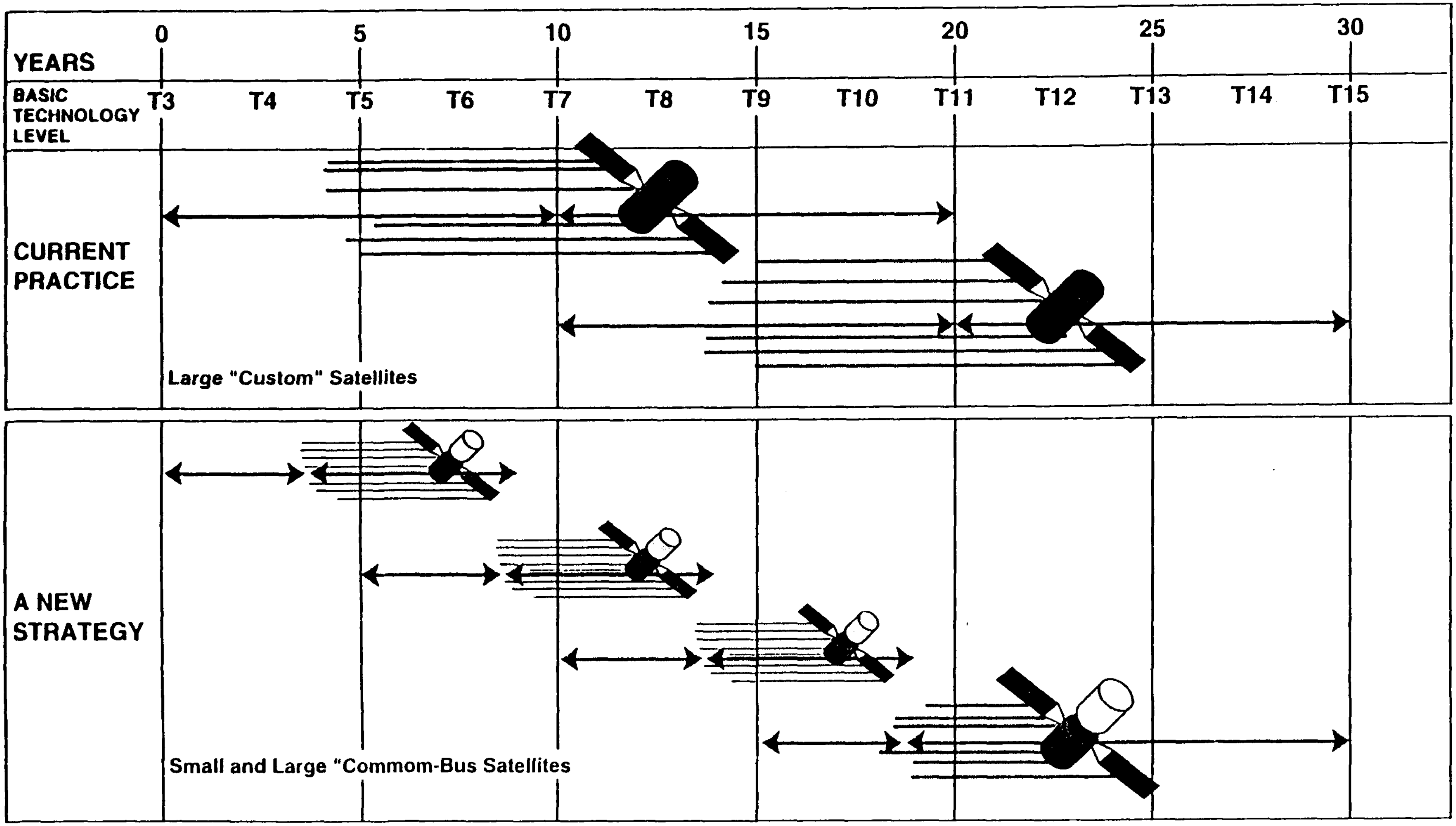
2876-04

Using Smaller Satellites to Rapidly Insert Technology and Shorten Acquisition Time for Larger Satellites

An alternative strategy has been conceived to enable the affordability and capability improvements needed to support future space architecture modernization. It calls for use of smaller, capable satellites to simultaneously demonstrate the utility of emerging technologies, provide an affordable vehicle for routine technology insertion into existing architectures, and potentially, to perform as an operational complement to larger satellites. Because the smaller satellites are less expensive, more risk can be taken in using newer technologies, in streamlining the acquisition and management approach, and in verifying the operational value of desired system requirements. Subsequent upgrades to larger satellites can be accomplished more quickly and efficiently because the new technologies, concepts and requirements have already been proven on smaller satellites. Adopting this approach is expected to significantly reduce the time for acquiring larger satellites. In a world of rapid change, our space systems must keep up with the unexpected, but not if it takes 10 years to field them. Thus, along with being a vehicle for technology insertion, smaller satellites also may hold considerable promise for augmenting backbone satellite capability, providing tailored coverage and responsive architectural flexibility as needs dictate.

USING SMALLER SATELLITES TO RAPIDLY INSERT TECHNOLOGY AND SHORTEN ACQUISITION TIME FOR LARGER SATELLITES

Advanced Systems Technology Office



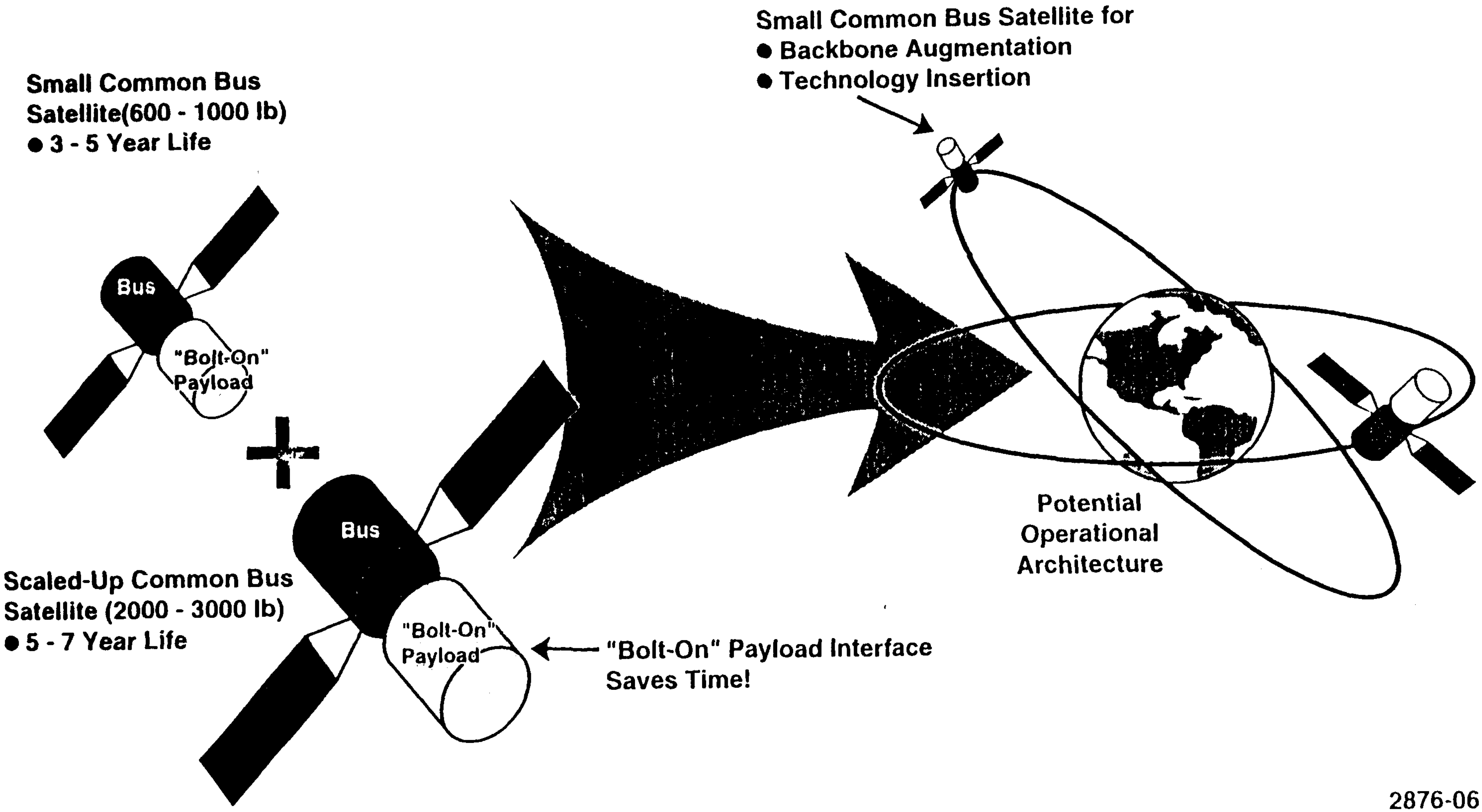
2876-05

Using "Common Bus" Satellites to Significantly Reduce Life-Cycle Costs

An equally important component of the strategy seeks a new direction in the way satellites (both small and large) are built. Specifically, using "common bus" satellites with a "bolt-on" payload interface to support a wide spectrum of missions across multiple satellite constellations is expected to offer significant savings in life-cycle costs. Emphasizing "common bus" vice customized satellites should drive down the non–recurring engineering costs and aid in simplifying ground operations through the use of common ground stations. Employing a "bolt-on" payload interface will enable concurrent payload and bus development that, in turn, could reduce satellite integration and test time by at least 50 percent. Finally, through improved payload mass fraction, equivalent capability could potentially be obtained from an architecture comprised of dual (small/medium) common bus satellites vice one populated with only large satellites. The net effect could be a significant reduction in launch costs and space segment life-cycle costs. The common bus/"bolt-on" payload concept also opens new dimensions in acquisition and operational flexibility by creating an environment for quick adaptation and response to changes in procurement, budgets or operational needs.

USING "COMMON BUS" SATELLITES TO SIGNIFICANTLY REDUCE LIFE CYCLE COSTS

ARPA
Advanced Systems Technology Office



2876-06

DoD Space Cultural Changes

What I have been describing are the enabling concepts for bringing about fundamental cultural changes to the DoD space business. It is safe to say that developing the technology associated with these concepts won't be nearly as difficult as overcoming the cultural barriers built up over the years within Government and industry. ARPA firmly believes that industry must be a full participant to ensure success in bringing about this change. I solicit your support and challenge you to be innovative and creative as ARPA moves forward.

ARPA
Advanced Systems
Technology Office

DoD SPACE CULTURAL CHANGES

• USE SMALLSATS FOR RAPID, AFFORDABLE CAPABILITY INSERTION & MODERNIZATION →	REDUCES ACQUISITION RISK
• EMPHASIZE COMMON BUILDING BLOCKS VICE CUSTOMIZATION →	REDUCES ACQUISITION COST
• DECOUPLE PAYLOAD FROM BUS DEVELOPMENT & TEST (BOLT-ON INTERFACE) →	REDUCES ACQUISITION TIME

2876-07

Economics of Cultural Changes

If nothing else, the economics of cultural change should be enough motivation. Today's custom-built, large satellites cost an enormous amount -- which means that there is limited ability to get new and different capability into space. Also note that when a new satellite is developed a large fraction of the total cost (O&M not included) is non-recurring. This translates into high schedule and cost uncertainty.

The new paradigm is to use small satellites (with a common bus and "bolt-on" payload interface) to rapidly insert new capability into space at a fraction of the cost while minimizing the non-recurring engineering (i.e., risk) in doing so. By developing a smallsat bus that is scalable, a similar condition will exist for mediumsats. For many missions, a combination of small and larger common bus satellites (Dual Common Bus) will provide excellent capability at an extremely affordable price. All the benefits of having a small satellite as an integral part of the architecture accrue the ability to:

- Gracefully insert new capability
- Affordably modernize the architecture
- Rapidly respond to changing threat or procurement condition

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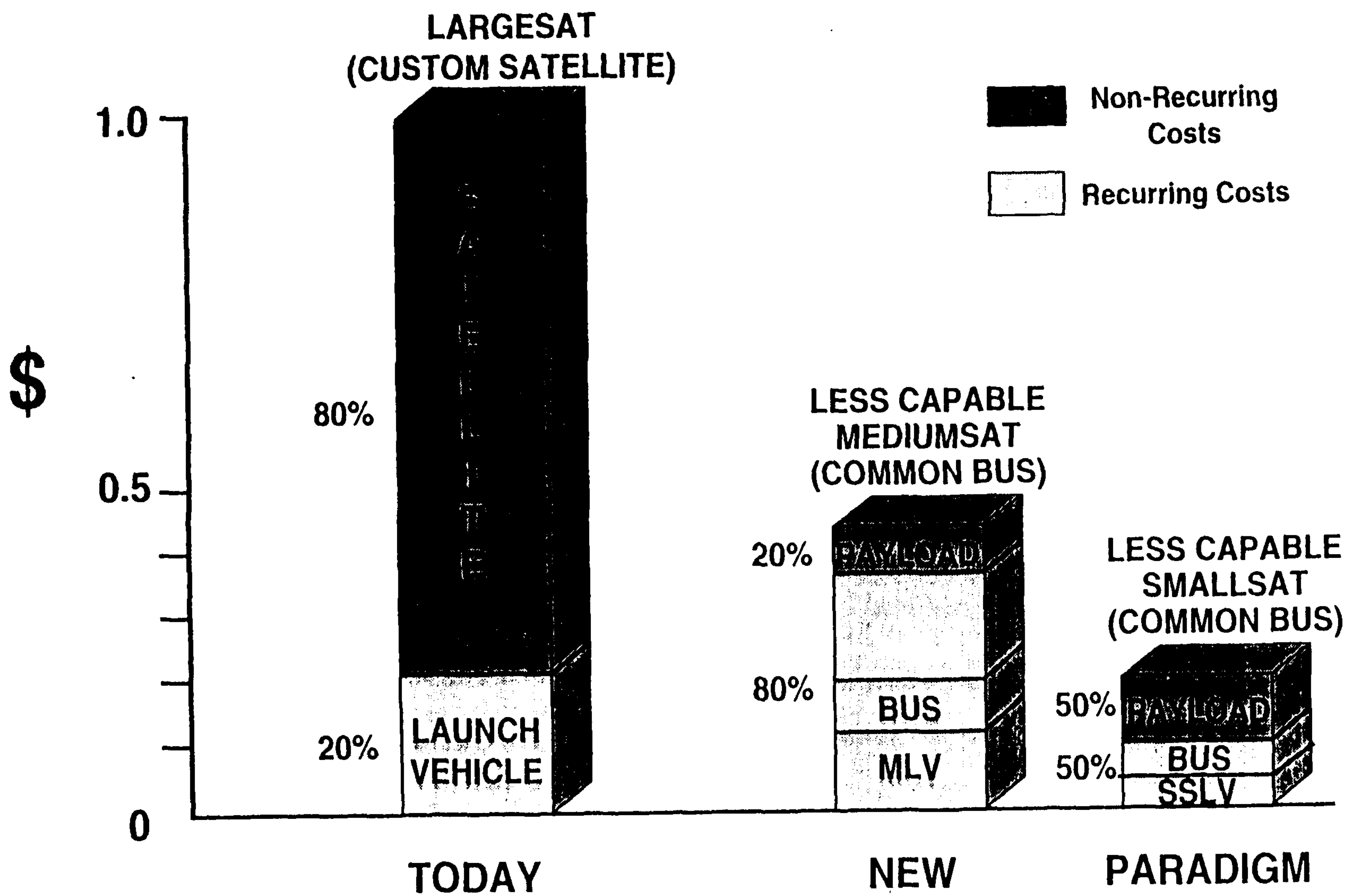
Advanced Systems Technology Office

ECONOMICS OF CULTURAL CHANGE



Note: Achieving Equivalent Architecture Capability With Smaller Satellites is the Challenge

2876-08

Foundational Technology Efforts Enable the Affordability Improvements

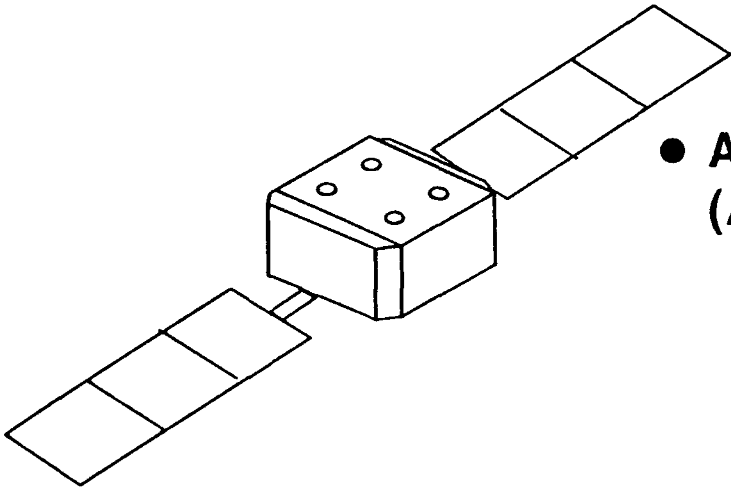
Two technology efforts clearly stand out as foundational for enabling satellite affordability improvements: the ARPA-sponsored Standard, Small Launch Vehicle (SSLV) and the Advanced Technology Standard Satellite Bus (ATSSB) programs. The SSLV goal is to provide low cost access to low-earth orbit (LEO) for satellites weighing up to 2,000 pounds, as well as a flexible, responsive launch capability. The ATSSB, with high performance, very high payload mass fraction and "bolt-on" payload interface represents the advanced common bus to enable big jobs on small satellites for a variety of missions and orbits. The ATSSB's scalable design will permit development of a larger common bus derivative to support heavier payloads and longer mission durations, as called for in the new strategy. It should be obvious that not only DoD, but also the civil and commercial space communities, would directly benefit from these innovations and affordability breakthroughs, and the resulting technologies will be applicable to any size satellite.

FOUNDATIONAL TECHNOLOGY EFFORTS ENABLE THE AFFORDABILITY IMPROVEMENTS

Advanced Systems Technology Office

Taurus™

- Standard Small Launch Vehicle Opens Market Niche
  - Less Costly Access to Space for Smaller Satellites
  - Flexible/Responsive Launch Capability



- Advanced Technology Standard Satellite Bus (ATSSB) Enables Big Jobs on Smallsats
  - Scalable, High Performance Common Bus
  - Supports Wide Range of Operational Missions
  - 100% Improvement in Payload Mass Fraction
  - "Bolt-On" Payload Reduces Acquisition Time/Cost
  - Low Recurring Cost

Civil/Commercial Applications Directly Benefit From Breakthrough!

2876-09

Key Advanced Technology Demonstrations and Payoffs

Several ARPA-sponsored ATDs, together, would validate the technologies and concepts to enable the new strategy for affordable space architecture modernization and, at the same time, help address capability shortfalls existing today in DoD MILSATCOM and remote sensing space systems. The objectives and payoffs of each ATD are summarized below.

The **Advanced Technology Standard Satellite Bus (ATSSB)** program will develop a scalable, high-performance common bus capable of supporting a variety of high mass fraction payloads in LEO to geosynchronous orbits. Payoffs include: a scalable, low recurring cost, common bus capability providing a testbed for emerging technologies; the potential for subsequent use in both defense and civil space architectures with attendant large savings in life-cycle costs; and validation of a small satellite role in operational architectures.

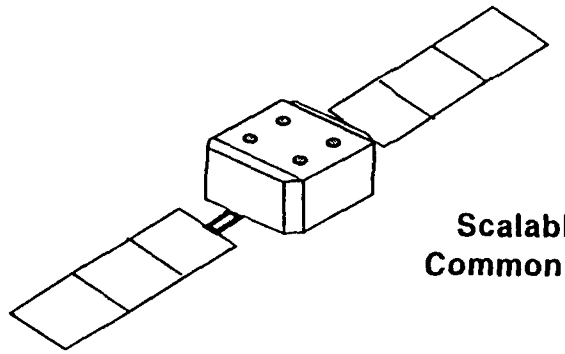
The **Advanced Satellite Technology and EHF Communications (ASTEC)** program will demonstrate critical EHF payload technologies capable of being integrated into a payload and hosted on the ATSSB in geosynchronous orbit to support MILSATCOM modernization.

The **Collaboration on Advanced Multispectral Earth Observation (CAMEO)** program will demonstrate a "dual-use" multispectral payload hosted on the ATSSB in low earth orbit to support future DoD/civil remote sensing satellite modernization. Payoffs include: an affordable "dual-use" capability for high priority DoD/civil remote sensing applications; a low cost, common ground station for joint DoD/civil operations; validation of the common bus for future remote sensing satellites; and a satellite collection resource to facilitate new commercial remote sensing markets.

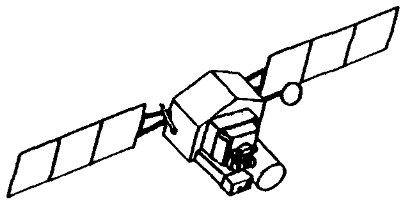
The **MILSATCOM Terminal Technology (IMPACT)** program will demonstrate improvements in future MILSATCOM terminal affordability, interoperability and mobility. Payoffs include significant reductions in the cost of developing, maintaining and operating future MILSATCOM terminals.

KEY ADVANCED TECHNOLOGY DEMONSTRATIONS AND PAYOFFS

Advanced Systems
Technology Office



ATSSB
Scalable, High Performance
Common Bus (LEO-GEO Orbits)



CAMEO
"Dual-Use" Multispectral
Payload Hosted on ATSSB
Supports Remote Sensing
System Modernization

ATSSB

- *Large Savings in Space Architecture Life Cycle Costs*
- Validates Smallsat Role – Affordable Capability Augmentation/Tech Insertion

ASTEC

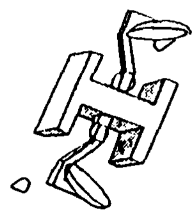
- Improved Comms Flexibility/Global Grid Connectivity
- Enables Smaller, Less Costly Polar Adjunct Communications Service

CAMEO

- Affordable, "Dual Use" Capability for High Priority DoD/Civil Remote Sensing Applications
- Low Cost, Common Ground Station for Joint DoD/Civil Ops
- Enables Commercial Remote Sensing Market

IMPACT

- Improved MILSATCOM Terminal Affordability, Interoperability
- MILSATCOM Terminal Connectivity to Commercial Global Grid



ASTEC
Advanced EHF Payload
Component Technologies

3281-12

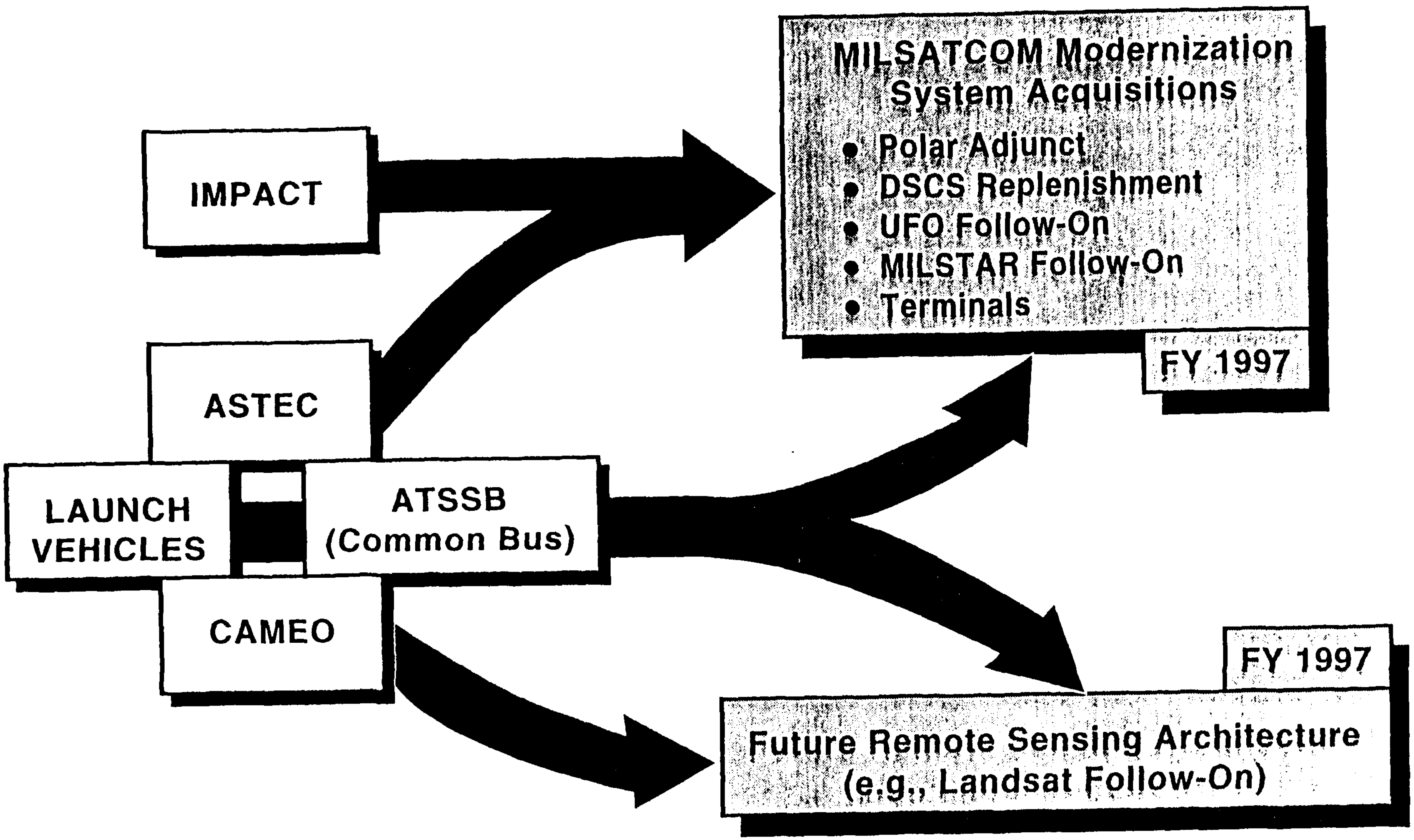
Advanced Technology Transition Opportunities

Adapting to the new strategy will be dependent on proper alignment of technology demonstrations with target system acquisitions. To even be considered for insertion into a major space system, technologies/concepts must be proven to the acquisition community at least prior to full scale development or, preferably, during concept exploration. A technology development and insertion approach that parallels the acquisition community's baseline space system modernization plans will mitigate the risk of failure. Once successfully implemented, the new strategy inherently permits affordable satellite modernization. The small, common bus satellites, as integral elements of the strategy, are used for continuous technology validation and insertion and, as needed, for capability augmentation.

During the mid- to late-1990s, a window of opportunity will exist to apply the new strategy for modernizing next-generation MILSATCOM and remote sensing space systems. This opportunity will be present because the existing operational MILSATCOM and remote sensing constellations will face block change decisions during this period. The ARPA-sponsored ATDs constitute a major risk reduction activity by demonstrating the advanced technologies/concepts to produce future MILSATCOM and remote sensing satellites at lower cost.

ADVANCED TECHNOLOGY TRANSITION OPPORTUNITIES

Advanced Systems Technology Office



Bottom Line

Self-Explanatory

ARPA
Advanced Systems Technology Office

BOTTOM LINE

- EVOLUTIONARY SPACE ARCHITECTURE MODERNIZATION CAN BE ACHIEVED WITH SIGNIFICANT SAVINGS!
  - *Advanced Technologies and Use of Small, Capable Satellites Hold Promise for Enabling the Affordability Improvements*
- APPROVED DoD ATDs (ATSSB, ASTEC, CAMEO AND IMPACT) WILL VALIDATE THE KEY TECHNOLOGIES / CONCEPTS
  - *MILSATCOM / Surveillance Capability Shortfalls are Simultaneously Addressed*
- A NARROW WINDOW OF OPPORTUNITY WILL EXIST, IN THE MID-TO LATE-1990s, TO CAPITALIZE ON THESE TECHNOLOGIES
  - *ATDs if Started Now, Will Transition Directly Into Planned MILSATCOM / LANDSAT Major System Acquisition*

FUTURE VISION

ARPA
Advanced Systems
Technology Office

AFFORDABLE SPACE ARCHITECTURE MODERNIZATION

Role of Technology and Small Satellites

2909-01

Projected Environment

There is universal consensus that DoD will become increasingly reliant on space systems to provide "war winning" leverage and global power projection. The key challenges will be to detect and negate time-critical fixed and mobile targets and to accommodate seamless sensor-to-shooter connectivity among highly dispersed, agile forces. This suggests that there are some important capabilities that must be addressed. But, at the same time, DoD is also faced with the reality of reduced budgets and fewer personnel to develop and operate future satellite systems.

FUTURE DoD SPACE CAPABILITY CONCERNS

ARPA
Advanced Systems Technology Office

KEY ISSUE IS SPACE SYSTEM AFFORDABILITY

- **High Cost/Time of Developing Space Systems May Preclude Adequate Modernization and Fielding of Needed Capability in Constrained Fiscal Environment**

- **Space Architecture Modernization <u>Must</u> Begin in Mid-1990s – Or Risk Gaps/Loss in Current Capability**
  - MILSATCOM Architecture (Polar Adjunct/SHF/UHF/EHF)
  - Landsat/Remote Sensing Architecture

- **Existing Capability Shortfalls <u>Must</u> Also be Overcome**
  - Lack of Repetitive, Wide Area Battlefield Coverage
  - Lack of Responsive Fusion, Dissemination and Direct User Access
  - Insufficient Comms and Wideband Connectivity to In-Theater Forces

Critical Efforts Must Begin, NOW, to Accomplish Above with Reduced Funding and, at Same Time, Significantly Lower Life Cycle Costs

2909-03

Current Practice and Cost Drivers Satellite/Architecture

Our current practice is to custom-build large satellites on roughly 10-year cycles. To avoid unacceptable program risk, only proven or space-qualified technologies are typically incorporated. Some of these technologies may become obsolete even before the first satellite is launched and, by the time the replenishment satellite is developed, the parts may no longer be available or the manufacturing processes changed to the point where redesign is necessary at considerable additional expense. The major factors driving the cost of satellite systems include requirements instability, large non-recurring engineering efforts, lengthy complex integration and testing (brought about by customization), expensive large satellite launches, complex satellite control and hardware obsolescence.

ADVANCED RESEARCH PROJECTS AGENCY
3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

July 12, 1993

MEMORANDUM FOR ASTO - DEMITRY

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

Reference is made to the following material submitted for clearance for open publication:

AFFORDABLE SPACE ARCHITECTURE MODERNIZATION
(ROLE OF TECHNOLOGY AND SMALL SATELLITES)

xxx The above referenced material was **CLEARED** for open publication by OASD(PA) on July 9, 1993, Case No 93-S-2493. All copies should carry the following Distribution Statement "A" as follows:

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G. T. Winn
Technical Information Officer

Attachments

PROJECTED ENVIRONMENT

Advanced Systems
Technology Office

- INCREASED RELIANCE ON SPACE SURVEILLANCE FOR GLOBAL "WAR WINNING" COMBAT STRATEGY

  CHALLENGE: PROLIFERATION OF TIME CRITICAL FIXED AND MOBILE TARGETS

- INCREASED RELIANCE ON SATCOM FOR GLOBAL POWER PROJECTION

  CHALLENGE: DISPERSED, REALTIME SENSOR-TO-SHOOTER AND C3 CONNECTIVITY

- REDUCED BUDGETS AND FEWER PERSONNEL

  CHALLENGE: LESS COSTLY SPACE SYSTEMS AND SIMPLIFIED OPERATIONS

Future DoD Space Capability Concerns

A key issue impacting future space architecture modernization is affordability. The high cost and time to develop space systems today and increasingly tight fiscal constraints can delay or preclude adequate modernization and fielding of needed capability. It is not unrealistic to imagine that the U.S. may eventually suffer gaps or even loss of critical space capabilities.

V-E READINESS AND TRAINING

COL ROBERT P. REDDY

3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

July 12, 1993

MEMORANDUM FOR ASTO - REDDY

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

Reference is made to the following material submitted for clearance for open publication:

ADVANCED DISTRIBUTED SIMULATION

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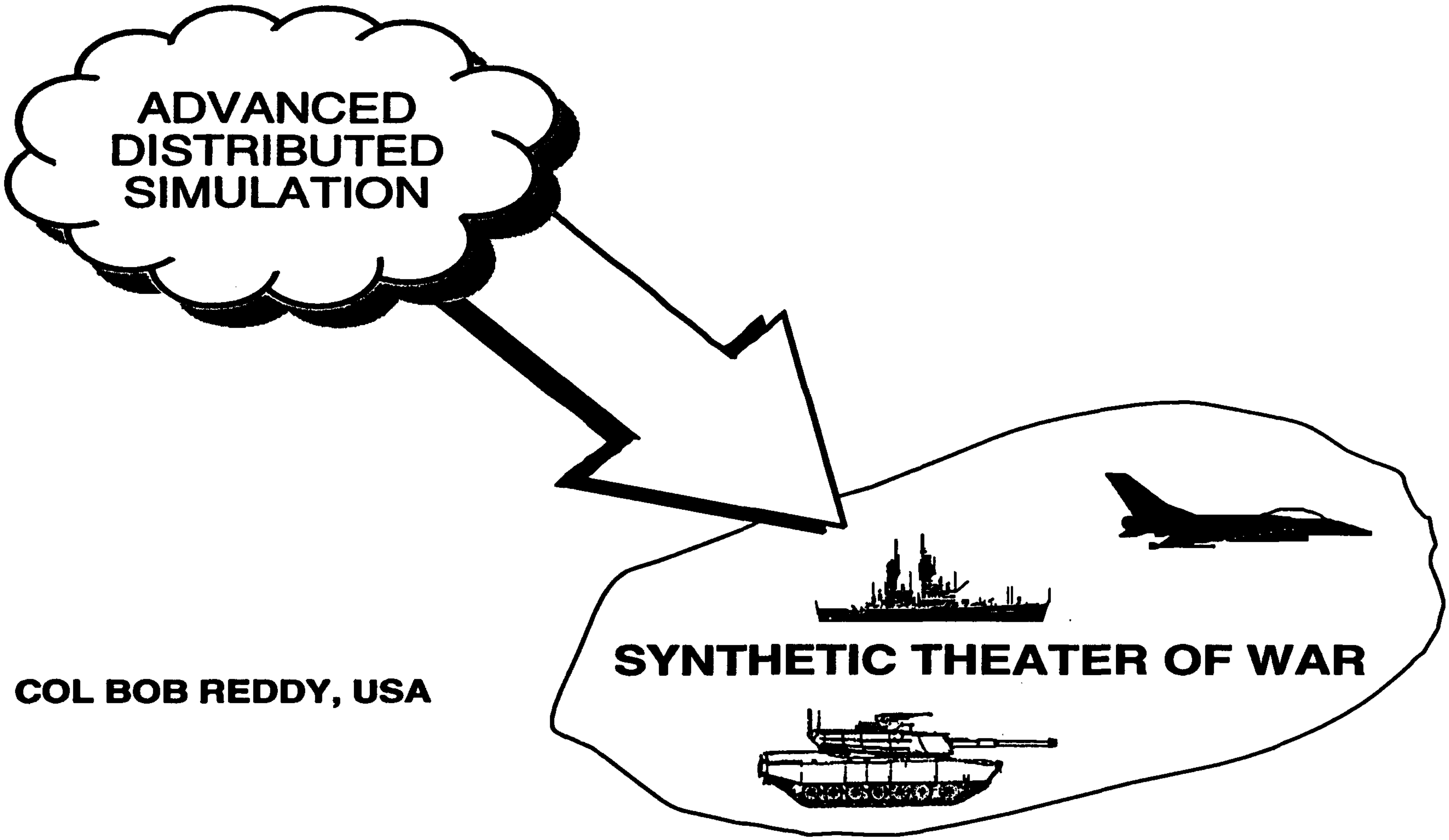
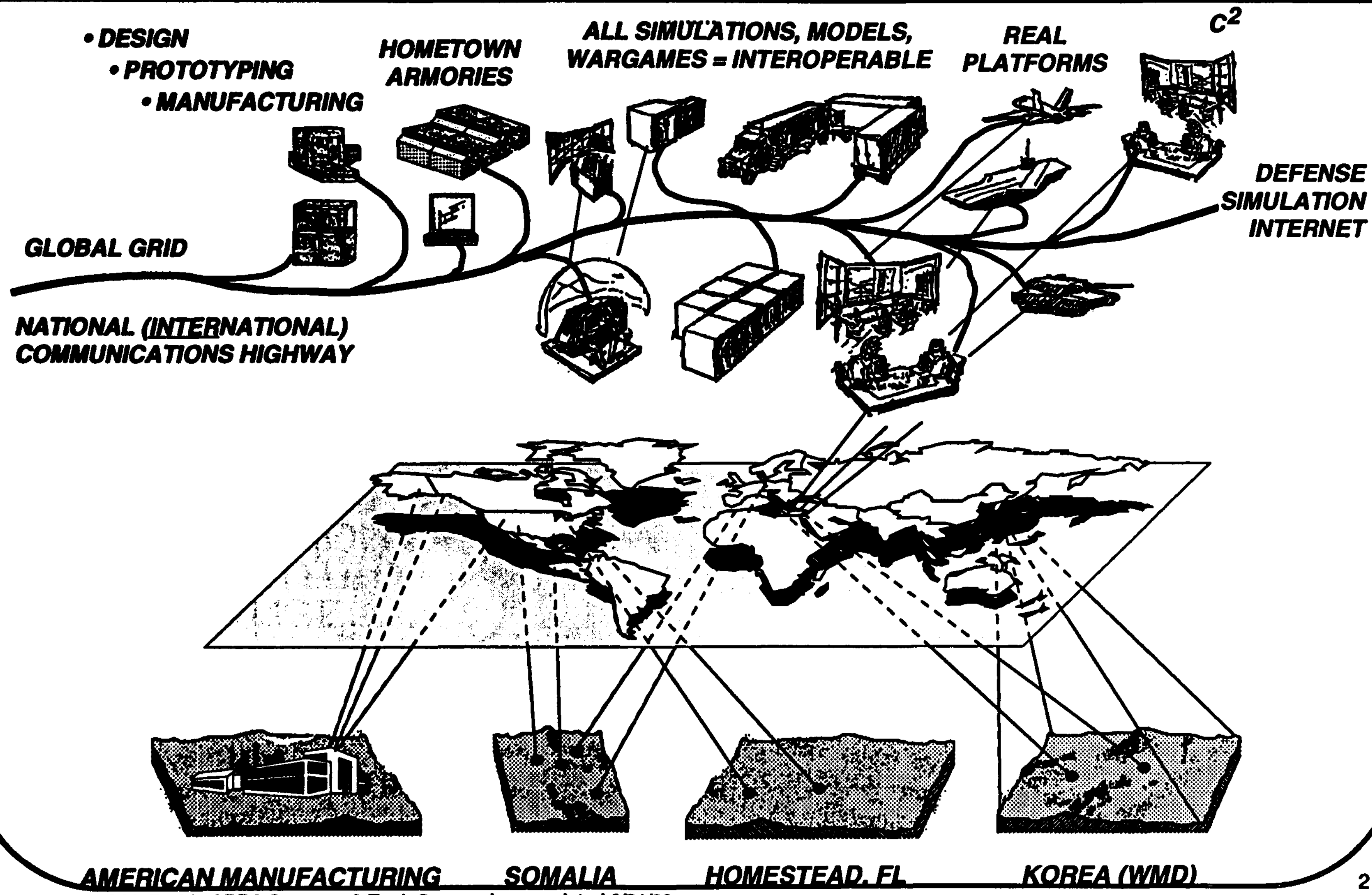
ARPA SYSTEMS AND TECHNOLOGY SYMPOSIUM



COL BOB REDDY, USA

ADVANCED DISTRIBUTED SIMULATION
THE VISION



COL Reddy ARPA Systems & Tech Symposium: updated 6/21/93

ADVANCED DISTRIBUTED SIMULATION
THE VISION

The ARPA Advanced Systems Technology Office is developing Advanced Distributed Simulation (ADS) technologies for Defense modeling and simulation applications.

The major effort under the ADS program, is the development of technologies necessary to create and demonstrate a Synthetic Theater of War battlespace. This effort began in 1992 and will include demonstrations in 1994 and 1997.

The vision of ADS is to bring warfighters and developers, from any location in the world, together in a synthetic environment with the necessary simulation technology to create a joint warfighting battlespace that represents weapon systems at the individual platform level of detail.

When fully developed the synthetic environment will allow warfighters and researchers to investigate a wide variety of relevant issues on an applicable piece of terrain that fulfills the operational or research requirements.

The technology will provide the capability for the interactions of many participants from numerous world-wide locations for interactive wargaming, for integrated research and development of new weapon systems or doctrine, or for the preparation for and execution of contingency operations.

The technology is being developed and demonstrated with operational user involvement. When it's determined that the technology is usable to service agencies it will be transitioned from the research and development effort to operational applications.

ADVANCED DISTRIBUTED SIMULATION

ARPA GOALS:

- By the year 2000 -- develop the ability to construct, on demand, a robust variety of synthetic environments to perform the following defense functions:
  - Joint / Service training readiness
  - Joint / Service doctrine refinement and development
  - Contingency planning, operations, AAR, and historical analysis
  - Support the acquisition process:
    - » Requirements definition
    - » Design
    - » Prototyping
    - » Manufacturing

ADVANCED DISTRIBUTED SIMULATION ARPA GOALS

Based on guidance from DDR & E, ARPA has established these goals to implement the vision of Advanced Distributed Simulation (ADS) and to enable ADS to meet the wide range of DoD modeling and simulation requirements.

The goal is to develop and transition to the CinC's, Services, and DoD agencies the required technologies for a defense wide infrastructure to permit the conduct of the full range of simulated operations in a Synthetic Theater of War (STOW). The program will create and demonstrate a seamless simulated environment that will be usable across the spectrum of doctrine, operations, training, materiel, and logistics for forces assigned to the Department of Defense. When completed, the Synthetic Theater of War will provide a technology base to fulfill CinC and lower echelon commanders and staff requirements to participate in the full range of actions associated with joint interoperability and warfighting.

The general approach is to (1) integrate and leverage key technologies emerging from the civilian research and development efforts, from various ARPA programs and from other exploratory development programs; (2) develop and refine these capabilities in prototype form, to test them in a simulation test bed, and (3) validate them in important military applications that are selected to stress the technologies effectively while providing capabilities that can be effectively transitioned to CinC's, all Service components and DoD agencies. In addition certain key technologies will be demonstrated in smaller "mini-demonstrations" which replicate a specific aspect of the spectrum of conflict and transition the technology to the service components.

The near term (FY '93 - FY '94) goals of the program are to demonstrate core technologies, in a testbed and "mini-demonstrations" to faithfully represent selected elements of the full spectrum of conflict, both horizontally and vertically, for up to a Joint Task Force level. The mid-term (FY '95 - '97) goals of the program are to faithfully represent the full spectrum of conflict for up to the Theater level. This synthetic environment will be a distributed, very detailed but aggregatable simulation that will seamlessly interoperate with real systems when required and provide for human interaction at all appropriate command levels. The long-term (FY '97-'00) goals are to transition the technologies to the service components for their joint or service specific use and application for: training readiness, development of joint of service specific doctrine, contingency planning, after action reviews, historical analysis, requirements definition and acquisition.

ADVANCED DISTRIBUTED SIMULATION
THE RATIONALE

- Resolves at weapons level of detail
- Focus on maneuver and firepower
- Supports current operational concepts
- Replicates dynamic battlespace
  - Synchronization
  - Agility
  - Maneuver
- Promotes joint warfighting

ADVANCED DISTRIBUTED SIMULATION
THE RATIONALE

The successful demonstration and integration of ADS technologies will directly and significantly improve the capability of the CinC's and Services to train, to maintain operational readiness, to develop joint and service doctrine, and to prepare contingency plans. Moreover, it will provide the infrastructure for enhancing the capabilities of the services to define requirements and to prototype new systems as a part of the acquisition process.

ADS resolves interactions at the weapons systems level of detail thereby allowing a focus on maneuver and firepower which is missing in current constructive models. This level of detail allows the warfighter or developer to more accurately capture and understand the results of engagements during simulation. The dynamics of active combat are closely replicated on the electronically shared battlespace with realistic interactions of soldiers in the loop and computer generated forces. Critical decisions and actions for battle synchronization, integration and maneuver are accomplished in simulation by soldiers as they are in active combat.

Accurate representation of the dynamic battlespace supports current operational concepts such as synchronization, agility and maneuver. The flexible capability of distributed interactive systems, allows warfighters to practice, refine and rehearse current operational concepts to satisfy desired objectives.

Joint warfighting is a demanding challenge. The ability to bring warfighters together from anywhere in the world via networking technology promotes joint warfighting at an affordable cost. Force maneuver and firepower can be practiced without the expensive and sometimes dangerous aspects of deploying large numbers of forces to field exercise locations.

ADVANCED DISTRIBUTED SIMULATION TECHNOLOGY DEVELOPMENT

Key Technologies:

- **Defense Simulation Internet**
- **Scaleability**
- **Semi-Automated Forces (SAF)**
- **Environments Development**
- **Instrumented real systems**
- **Low cost computer image generation**

ADS TECHNOLOGY DEVELOPMENT

There are six key ADS technologies which are the focus of ARPA's efforts to build the Synthetic Theater of War.

Although the Defense Simulation Internet is not, strictly speaking, a technology, it will require significant strides in networking and communication technologies to support the 1997 ADS goal of 100,000 entities operating in perceptible real time.

Improvements in scaleability of two orders of magnitude will be required to increase effective bandwidth of our networks and reduce simulation processing power to meet our goals.

The development of more behaviorally accurate semi-automated forces will improve the intelligent execution of military missions that more accurately reflect the behavior of humans in similar operational situations.

The development of environmental effects will improve the speed that required operational area digitized terrain is prepared and delivered. Additionally, this development will provide for representation of more realistic dynamic environment (smoke, fog, fires) as it occurs in an operational combat area.

Demonstrating the value added of linking instrumented *live training ranges* into the synthetic environment will provide insights into the requirement for developing mobile instrumented systems that are linked to command and control systems.

Computer Image Generators will be upgraded, as required, to support the dynamic environmental representations. Much of the technology push in this area will come from the marketplace.

Instrumented real systems and low cost computer image generators will not be discussed in detail.

DEFENSE SIMULATION INTERNET PROGRAM OBJECTIVES

- Develop networking and wide-band communications technology to support the ADS vision
- Provide robust, near real time communications support for ADS technology development, and the defense modeling and simulations community
- Field and support worldwide DSI sites with capability for data, video, voice and graphics transmission
- Provide secure communications over unclassified network
- Incrementally transition DSI functions to DISA as various component technologies mature

DEFENSE SIMULATION INTERNET PROGRAM OBJECTIVES

The goal of the Defense Simulation Internet (DSI) infrastructure program is to develop the communications infrastructure required for advanced distributed simulation applications. The infrastructure will provide connectivity on a single internetted system that is physically distributed, multi-media capable and supports dissimilar simulation devices. The network will be flexible and expandable using commercial-off-the shelf equipment and will enable economical, high bandwidth capacity communications. It will also provide secure DoD Secret Subnets in the near term and ultimately Top Secret and SCI subnets.

The DSI is a high-capacity network testbed to support a full spectrum of warfighting simulation interoperability activities in order to expand the commercial networking technology base available for defense modeling and simulation. It will develop the experience base leading to standards for expanded DoD use of advanced warfighting simulation applications.

The DSI is a robust, near real time communications capability for military modeling and simulation exercises. The network will be further developed during the next few years to provide this capability to a wide range of modeling and simulations applications.

Although much of the progress in this area will be driven by progress in the civilian arena. The DSI can also provide an immediate testbed for the "National Information Superhighway".

The network will be transitioned to DISA for operational management.

DEFENSE SIMULATION INTERNET TECHNICAL APPROACH

- Provide dynamic routing of network traffic with bandwidth reservation (ST2)
- Provide enhanced network encryption devices
- Develop multi-vendor router capability
- ATM protocols and larger WAN (backbone) capacity (FY 94)
- Support robust network traffic (now T1 w/1.5 Mbps to T3 w/45 Mbps for 94 to OC3 w/155 Mbps for 97)
- In partnership with NSA, develop and field ATM-speaking NETWORK encryption devices capable of OC3 network traffic level (FY 94-FY 96)

DEFENSE SIMULATION INTERNET
TECHNICAL APPROACH

The technical approach for development of the DSI network has several key elements that require coordination between ARPA, DISA and the commercial communication carriers. The goal is to develop and field technologies that are compatible with the latest commercial communications network to support defense modeling and simulation applications.

Development of protocols for the dynamic routing of message traffic and reservation of bandwidth is a key technology that will allow the simulation users to use the network for a variety of applications with minimum setup time and expense.

Network encryption devices will allow defense users to conduct exercises at various levels of security classification, to meet the needs of the modeling and simulation application.

Most of the required network technology and communication technology development will be provided by the civilian sector.

SCALEABILITY OBJECTIVES

- Two orders of magnitude growth in real time data exchange from large number of remote sites by 1997
- Evolve technology consistent with strategic vision of National Information Infrastructure
- Facilitate commercial development of ATM protocol functionality
- Investigate multiple paths which interact close to the application layer of the architecture

SCALEABILITY OBJECTIVES

Advances in both military and commercial communication technology are expected to support the bandwidth demands anticipated by Advanced Distributed Simulation. However, complimentary application specific services such as gateways (routers) for LAN-MAN-LAN interconnection are not. It is in this area and in the connection of devices into heterogeneous networks that the scaleability technology effort is concentrated. Generalization of the approaches developed in specific demonstrations is the ultimate objective with specific goals of lower cost and auto-configurability transparent to the operational user. Additionally, advances in technologies enabling multi-level simultaneous security operations is a critical developmental area.

The major objective for the scaleability development program is to provide data communications tools will allow the interactions and interoperations of 100,000 objects on the synthetic battlespace from numerous remote locations.

The results of this development will also be of interest to the development and implementation of the "National Information Superhighway".

The data communication tools must interoperate with the commercial development of the ATM functionality as well as the Distributed Interactive Simulation (DIS) protocols used for defense modeling and simulation purposes.

SCALEABILITY TECHNICAL APPROACH

- Evolve DSI to accept multi-cast groups
  - ATM standard
  - Encryption system
- Initiate analysis of best approach to reconfigure multi-cast groups dynamically and with agility
- Reduce communications requirements
  - Investigate application based filtering and compression techniques
  - Improve dead reckoning algorithms
- Investigate communications reduction techniques at all layers of the communications architecture

SCALEABILITY TECHNICAL APPROACH

Our most difficult technical challenge in the area of scaleability will be to develop a multi-cast capability that is both dynamic and agile. Although civilian technology is moving toward multi-cast routing of messages, the agility with which we must be able to reconfigure simulation nets is probably beyond any requirement in the civilian world.

We recognize this as perhaps our most challenging technology area and we are programming significant resources to generate a significant technology push.

SEMI-AUTOMATED FORCES OBJECTIVES

- Develop DoD baseline SAF architecture
- Develop behaviorally realistic, AI based platforms
  - SAF reacts appropriately to environmental effects
  - Tactical actions/reactions reflective of human behavior
- Develop behaviorally realistic representations of higher level command and control
- Extend SAF interaction to instrumented real systems
- Develop interactive data visualization system with fast future "what if" capability/after action review

SAF OBJECTIVES

The Semi-Automated Forces (SAF) are designed to provide a baseline capability that is usable for all DoD modeling and simulation applications. This is the baseline architecture for the Army's CCTT development effort. The current version of Semi-Automated Forces are being expanded horizontally and vertically to include all relevant forces available to a CinC.

The extension of Artificial Intelligent technology will provide, intelligent, automated forces at higher echelons of command. Success in this endeavor will create a paradigm shift eclipsing traditional Lanchestrian/Monte Carlo based constructive wargaming models.

These forces will be capable of interacting with instrumented real systems and manned simulators.

Interactive data visualization development will provide the capability for the warfighter or researcher to conduct fast future "what if" analysis. An advanced 3D debrief environment will be created to provide improved interactive debriefing at all levels in the chain of command. Exploitation of branch wargaming will provide a fast futures contingency simulation to advance the military planning process. This capability will improve the ability for simulations to support real contingency operations as well as more realistic after action reviews.

SEMI-AUTOMATED FORCES
TECHNICAL APPROACH

- Establish DoD level architecture baseline in 94; modular, expansible, expandable, interoperable
- Develop behaviorally realistic platforms
  - 94: Combine constructive and virtual
  - 97: AI based aircraft and tanks (only)
    Expert based ModSAF to populate battlefield
  - 00: AI based full functionality
- Higher level command
  - 94: Constructive simulation commanding ModSAF
  - 97: AI based BN level command (all services)
  - 00: AI based higher level command across all services

SAF TECHNICAL APPROACH

The baseline architecture (ModSAF) is modular, expandable and interoperable to allow researchers and vendors to modify or add to SAF functionality to satisfy a wide range of modeling and simulation requirements.

For the FY 94 demonstration, Semi-Automated Forces will be combined with constructive and virtual simulation systems. The FY 97 goal is to demonstrate limited artificial intelligent based SAF. Expert systems based SAF will be used to represent the balance of the forces required. By the year 2000, the goal is to represent the complete range of military functionality with artificial intelligence based SAF.

A major technology effort is underway to develop SAF command and control. In FY 94 command and control will be provided by constructive models. By FY 97 the goal is to provide AI based C^2 at the battalion level across all functionalities. This will be followed in FY 01 by AI based C^2 at the brigade level across all functionalities.

ENVIRONMENTS DEVELOPMENT

OBJECTIVES:

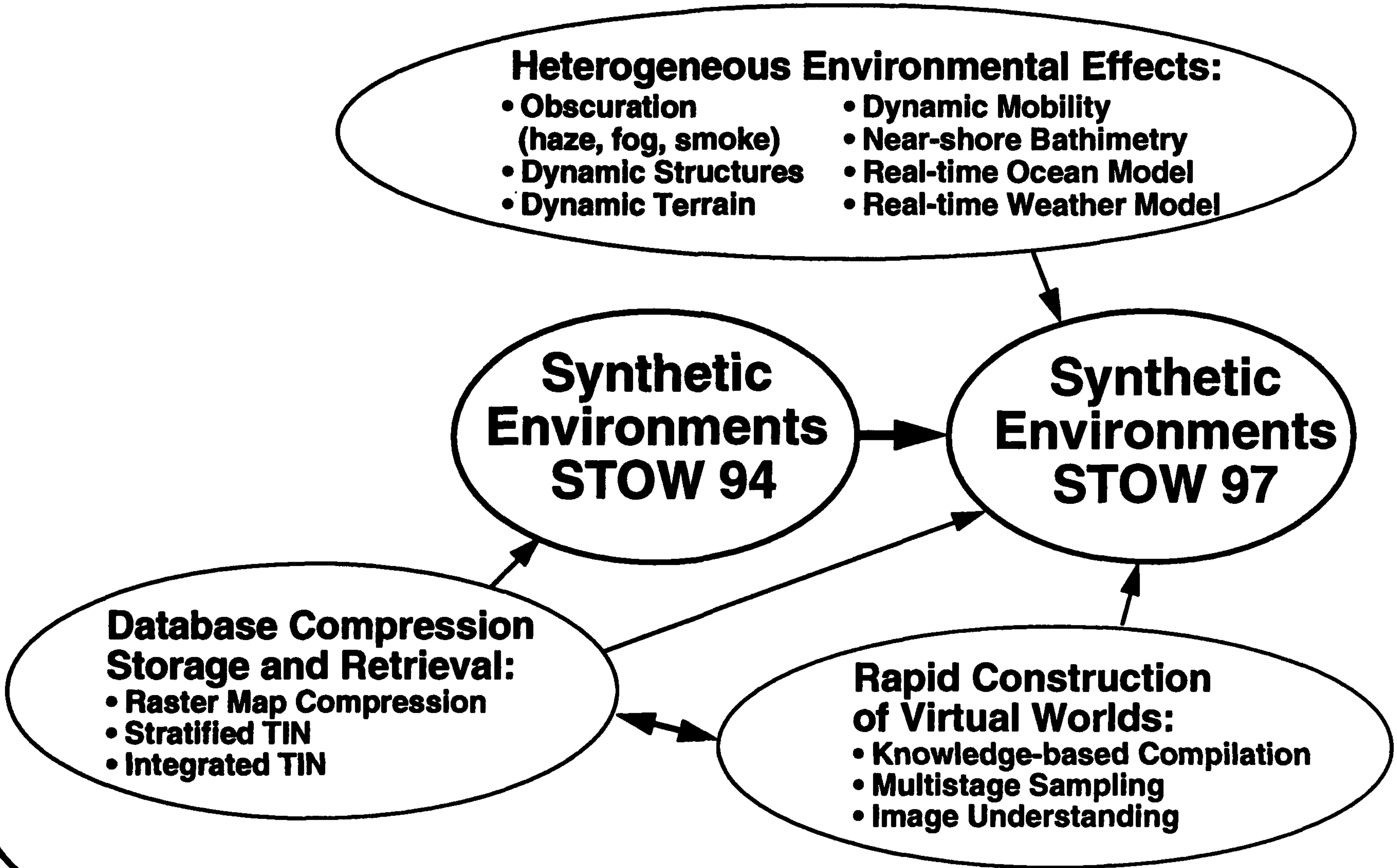
- Rapid Construction of Virtual Worlds
- Database Compression, Storage and Retrieval
- Heterogeneous Environmental Effects

ENVIRONMENTS DEVELOPMENT

Digitized terrain is the foundation for creating the synthetic battlespace. This digitized terrain provides the common terrain database for all of the distributed participants in an exercise. To support real world contingencies, we must be able to generate the required virtual terrain on short notice. At the same time we must be able, conveniently, to store and retrieve these data bases.

The development of this technology will also provide for heterogeneous environmental effects, e.g. rain, fog, and diurnal effects that naturally occur and combat generated effects, e.g., dust clouds, smoke and fires. The technology must also provide dynamic terrain which represents the realistic effects of combat on the terrain, e.g., destroyed bridges and bomb craters.

ENVIRONMENTS DEVELOPMENT TECHNICAL APPROACH



ENVIRONMENTS DEVELOPMENT TECHNICAL APPROACH

The effort to rapidly construct, compress, store and retrieve terrain databases has begun at the US Army Topographic Engineering Center, Ft Belvior, Va. The efficiency of this process will be improved during development to provide increasingly capable products for the FY 94 and FY 97 demonstrations.

The effort to develop the heterogeneous environmental effects will begin in FY 94 with demonstrations planned for FY 96 and FY 97. In addition to developing environmental effects which can be run by a viewer of the virtual world, we must insure that the impact of the environmental effects on semi-automated forces must be represented accurately and in real time. This may prove to be one of our more challenging technological issues.

SYNTHETIC THEATER OF WAR MISSION STATEMENT

- Demonstrate synthetic joint theaters of war by combining ADS technology and instrumented operational systems at existing national ranges in SWUSA.

- Demonstrate the applicability of ADS technology for readiness and operations, requirements determination, acquisition, and test and evaluation.

- ARPA lead with participation by JCS, Army, Air Force, Navy, Marine, DMA and DISA.

DDR&E Guidance to DARPA (27 Mar 92)

STOW MISSION STATEMENT

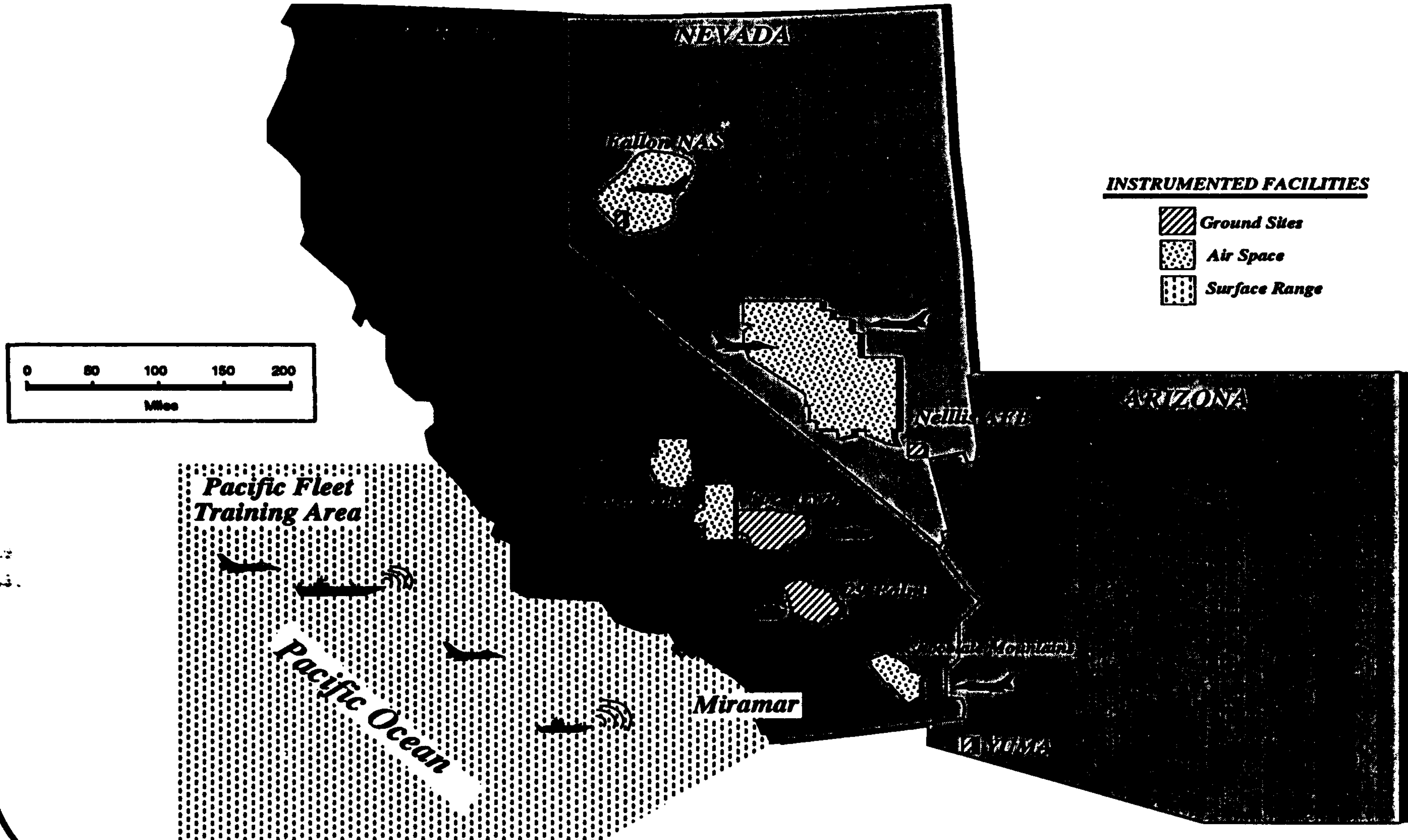
The strategic environment in which the United States operates has changed significantly in the past two years, resulting in the development of a new National Military Strategy. This new strategy places a greater emphasis on joint operations and will require the development of new service and joint doctrine. Readiness and training requirements for the force will increase to meet the uncertainty of the threat. At the same time, resources will continue to shrink, requiring the services to search for the most cost effective ways to meet the enhanced training and readiness requirements. Weapons system development will also require new technologies and procedures to insure systems are developed with the maximum capability in the minimum time at the lowest cost.

To support this new strategy, the Director of Defense Research & Engineering (DDR & E) formulated a new Science and Technology (S & T) strategy which includes S & T Thrust # 6, Synthetic Environments. As a major element in this thrust, in March 1992, DDR&E directed ARPA to develop and demonstrate a Synthetic Theater of War (STOW). From this directive the STOW mission statement has been refined.

STOW will leverage the expanding ADS technology base to demonstrate a Synthetic Joint Theater of War capability which will include linking existing ADS technologies with instrumented operational systems at existing national ranges in the SWUSA.

The Synthetic Theater of War battlespace will also provide the capability to simulate key aspects of the other six Science and Technology Thrusts and to demonstrate the applicability of ADS technologies to be used for requirements determination, acquisition or test and evaluation issues.

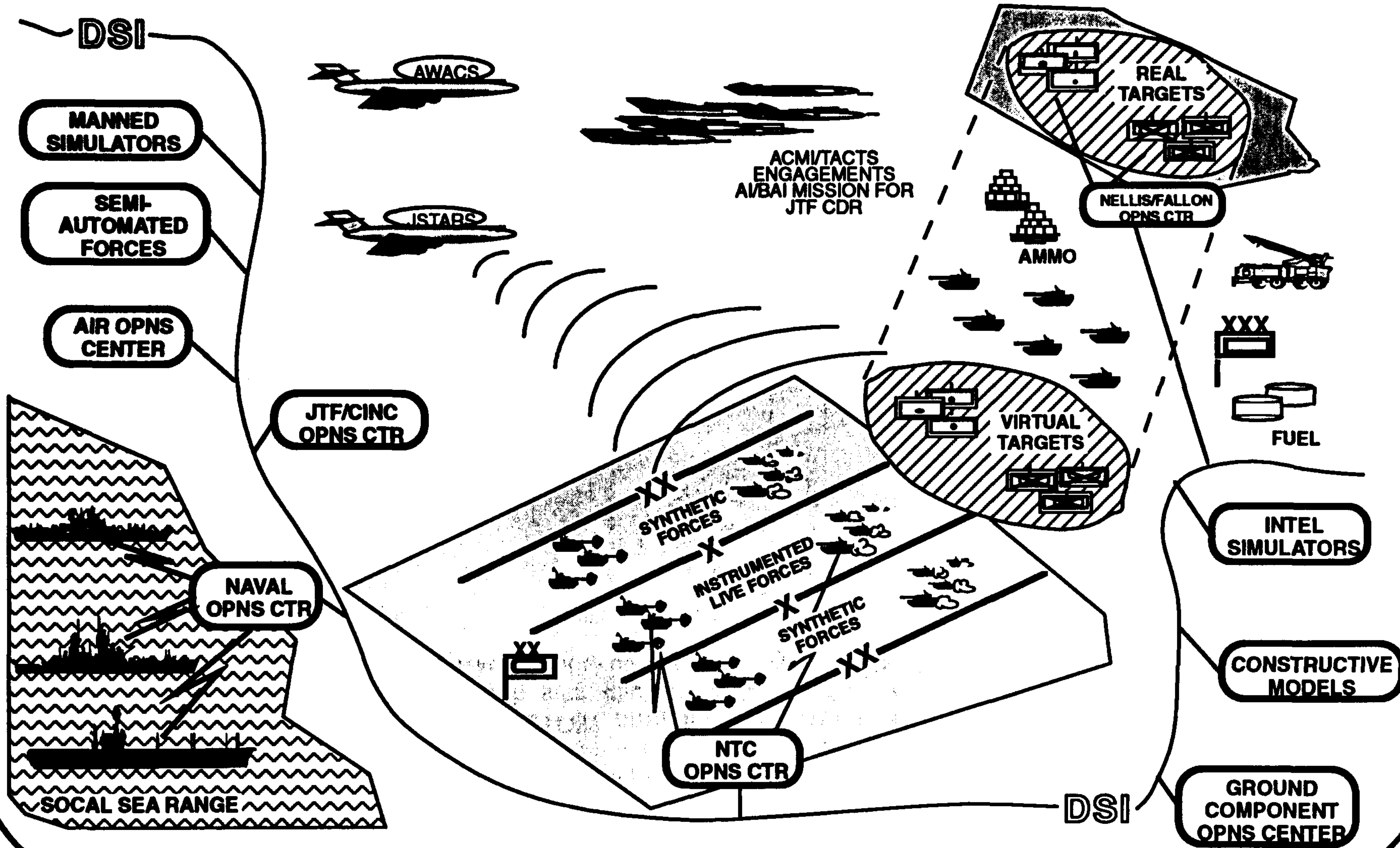
CAPITALIZE ON SWUSA TRAINING RANGES



CAPITALIZE ON SWUSA TRAINING RANGES

The services have developed "world class" training ranges in the Southwestern United States (SWUSA). Although these ranges are currently used for some aspects of joint training, they do not represent a coherent joint training environment. In FY 94, the STOW program will develop and demonstrate the technologies to interconnect these training ranges with synthetic forces under the command of a Joint Task Force (JTF) Headquarters to provide a robust environment to conduct JTF exercises or other relevant activities.

JOINT TASK FORCE OPERATIONS FOR PROOF OF CONCEPT



JOINT TASK FORCE OPERATIONS FOR PROOF OF CONCEPT

The FY 94 proof of concept demonstration for JTF operations will link the SWUSA training ranges with synthetic forces, all under the command of a JTF headquarters, to provide a robust environment for the conduct of a JTF exercise. This capability will allow the JTF commander to more effectively practice multi-echelon warfighting skills. The JTF and appropriate subordinate commanders and staffs will be located at their assigned home stations and fully and realistically interact with the operations being conducted in synthetic battlespace representing SWUSA.

The decisions and actions required of the distributed commanders and staff will mirror active combat. The robust capabilities of the synthetic environment, will allow more assets to be available to the JTF commander than would be expected in a normal peacetime exercise.

Virtual enemy formations and targets can be realistically created in the synthetic battlespace. These targets can be engaged by real or virtual weapon systems as assigned by the JTF commander. If the virtual targets are appropriate for air strikes, the commander can direct the destruction of the targets by high performance aircraft on instrumented air ranges. The results of the engagement on the instrumented range will be reported to the JTF commander and will affect the relevant force ratios and enemy force capability in the synthetic battlespace.

EVOLUTION OF ADVANCED DISTRIBUTED SIMULATION

STOW I 1-94

JOINT TASK FORCE

~ 10,000 Entities
~ 15 Locations

SAFOR
O-5 Level C^2
Combat Vehicles

Static Environment

Live Forces in SWUSA

DSI-T3

STOW II 1-97

JOINT THEATER

~ 100,000 Entities
~ 50 Locations

IFOR/SAFOR
O-6 Level C^2
Greater Functionality

Limited Dynamic Environment

Live Forces in SWUSA

DSI-OC3/ATM

STOW 2000+

SYNTHETIC THEATER OF WAR OPERATIONAL SYSTEM

>100,000 Entities
> 50 Locations, World-wide

IFOR
0-7 Level C^2
Full Functionality

Full Dynamic Environment
Rapid Terrain Generation

Live Forces Anywhere

DSI-OC 48

Evolution of Advanced Distributed Simulation

The ARPA Synthetic Theater of War (STOW) program plans to evolve ADS technology as shown on this chart. This expanded technology will provide enhanced capabilities for the services to conduct military operations in simulation.

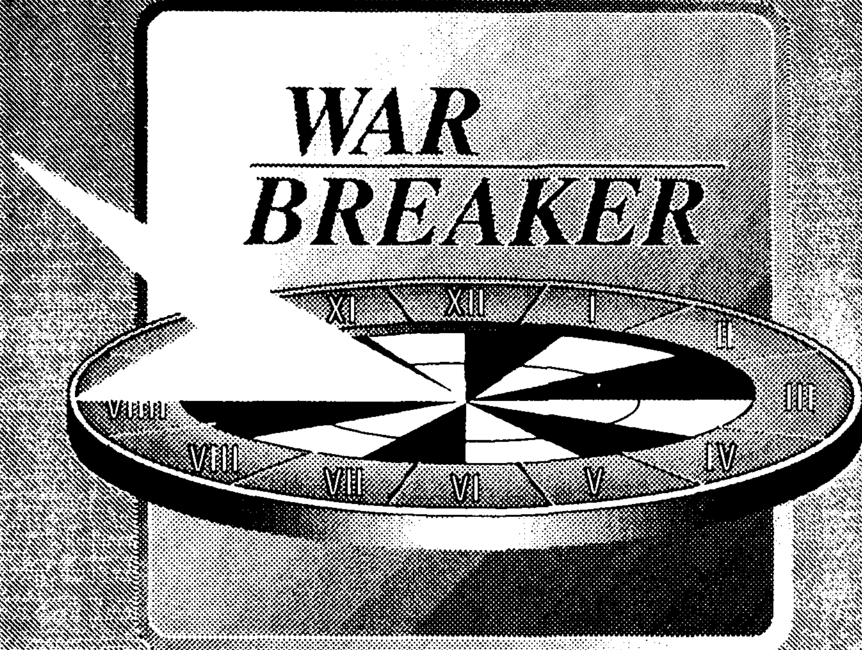
In STOW 1-94, the technology goal is to allow for the interactions of 10,000 PDU generating entities operating in perceptible real-time from 15 distributed locations. The concept will be demonstrated during a Joint Task Force (JTF) exercise that links Semi-Automated Forces (SAFOR), representing combat vehicles, with live forces at the SWUSA instrumented range complexes. These virtual and live forces will be augmented with constructive simulation models to provide a robust, static synthetic environment for a Joint Task Force to conduct military operations. The JTF will consist of an Army Division, an Air Wing, a Marine Brigade and a small Carrier Task Force.

In STOW 1-97, improvements in technology will be demonstrated during a larger Joint Theater exercise. This exercise will include a CinC, an Army Corps, an Air Division, a Marine Division and a larger carrier task force. The technology goal is to support the interactions of 100,000 PDU generating entities interoperating from 50 distributed locations. The synthetic forces will be simulated by SAFOR operating at the Brigade level with limited Artificial Intelligent capability. The synthetic environment will provide limited dynamic terrain and environmental characteristics.

Demonstrated techonologies will be transitioned to the services for their use and continued development as required. Further improvements in technology can be expected as shown on the chart.

V-F WAR BREAKER AND EVOLVING MILITARY TECHNOLOGY

DR. JUDITH A. DALY



SURVEILLANCE, INFORMATION AND TARGETING TECHNOLOGIES SUPPORTING SYNCHRONIZED, ACCURATE PROSECUTION OF TIME CRITICAL TARGETS

0075-93

SLIDE 2

Very quickly, just to give a perspective as to where the WAR BREAKER program is located within the DARPA organization. The Advanced Systems Technology Office, or ASTO for short, is located in the lower left hand corner of this organization chart and has the management responsibility for the WAR BREAKER program.

WAR BREAKER

PRESS CONFERENCE

93-S-0521

WHY WARBREAKER

ARPA

- ***DESERT STORM EXPERIENCE***
  - *Successful Exploitation of High Tech Weapons and Accelerated Combat Operations Tempo*
  - *Major Shortfall was in Targeting and Prosecution of the Time-Critical Targets*

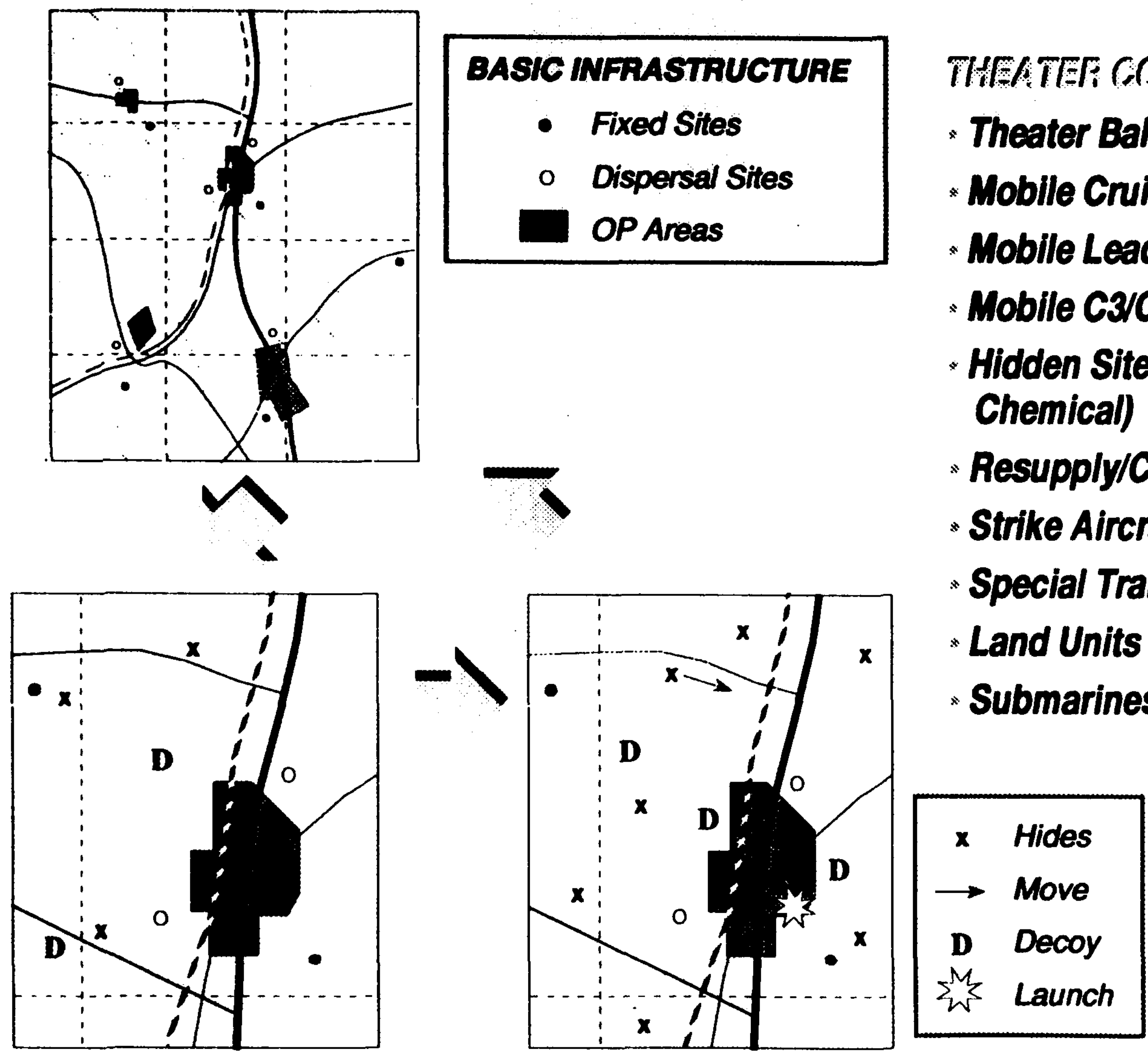
- ***GEOPOLITICAL UNCERTAINTIES OF THE FUTURE RESULTS IN***
  - *Proliferation of TCTs*
  - *Premium on High Leverage Technology*

SLIDE 6

This slide is a visual depiction of the Time Critical Target problem faced in Desert Storm and representative of the canonical problem of the future. As shown, the TCT generically consists of a basic infrastructure of fixed sites (garrison), dispersal sites and operating areas. The target exists within garrison until hostilities or the threat of hostilities, then it generally moves to dispersal sites until execution from a third location; that of the operating area (OP). The cycle is one of disperse, hide, deceive, move operate or launch and re-hide or return into the infrastructure for reload or refurbishment.

THE PROBLEM: TCTs

ARPA



DISPERSE, HIDE, DECEIVE

MOVE, OPERATE, RE-HIDE

THEATER COMMANDER'S CHALLENGE

- ***Theater Ballistic Missiles***
- ***Mobile Cruise Missiles***
- ***Mobile Leadership***
- ***Mobile C3/Control Centers***
- ***Hidden Sites (Nuclear, Biological, Chemical)***
- ***Resupply/Critical Materials Convoys***
- ***Strike Aircraft***
- ***Special Trains***
- ***Land Units***
- ***Submarines/Surface Ships in Port***

SLIDE 7

This slide depicts the challenges of the TCT problem as demonstrated on the last slide. Success against the TCT requires a highly developed situational awareness over a large geographical area. It also requires a timely and accurate assessment of the enemy intentions, a rapid detection and classification of deep-hide targets with minimal false alarms, and a quick and accurate targeting capability.

CHALLENGES OF THE PROBLEM

- ***DEVELOPMENT OF SITUATION AWARENESS OVER A WIDE AREA***
  - *Assessment of OOB and Doctrine*
  - *Assessment of Hide Sites, Movement Routes, of OP Areas*
  - *Accurate Development of Data Histories in Retrievable Format*
- ***TIMELY ASSESSMENT OF ENEMY INTENTIONS IN THE FACE OF RAPIDLY EVOLVING SITUATIONS***
- ***RAPID DETECTION/CLASSIFICATION/NOMINATION OF "DEEP HIDE" TARGETS WITH MINIMAL FALSE ALARMS***
- ***PLANNING/REPLANNING OF OFFENSIVE ACTIONS WITHIN ENEMY TIME CYCLES***
- ***DEVELOPMENT OF ACCURATE TARGETING INFORMATION TO SUPPORT PRECISION STRIKE AGAINST TIME CRITICAL TARGETS***

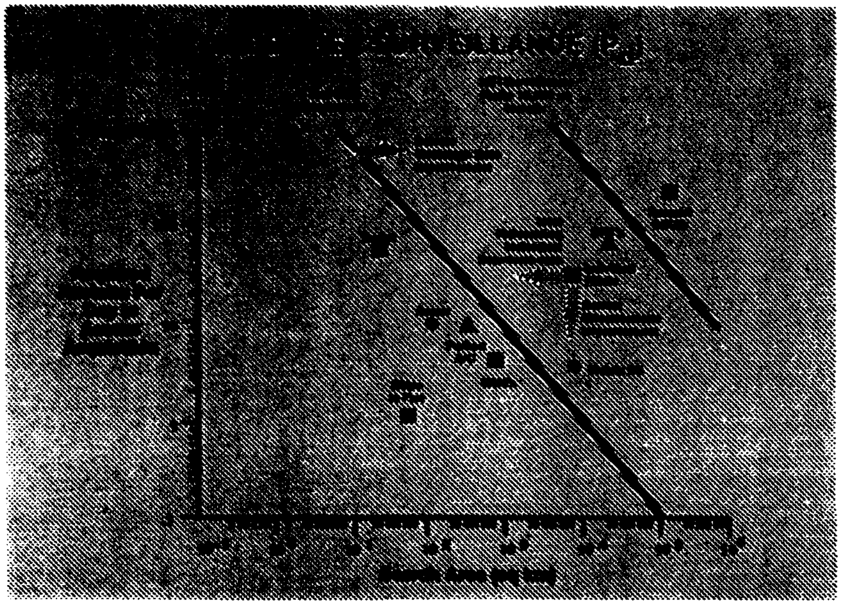
SLIDE 8

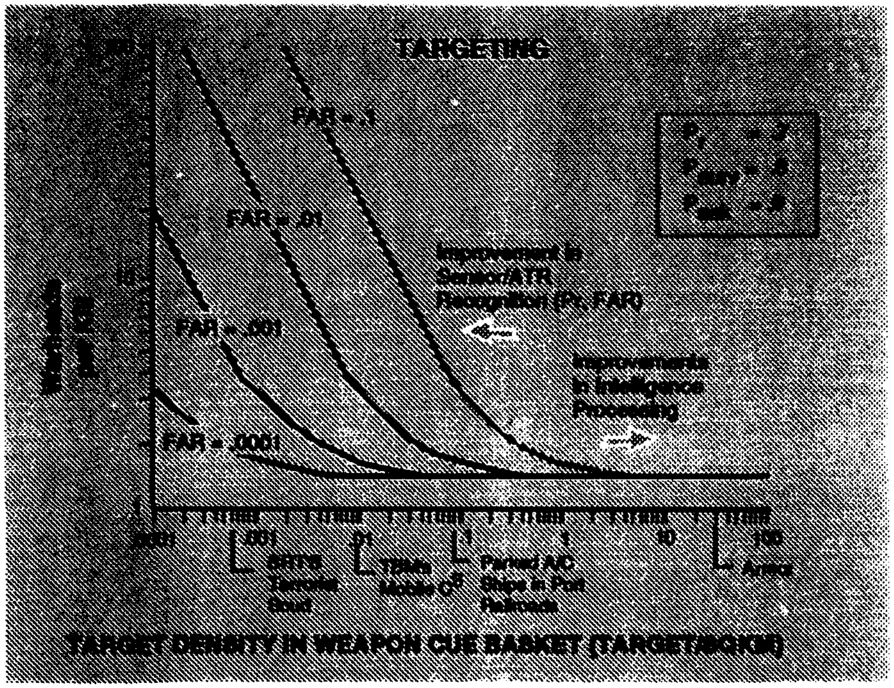
This slide helps us explore why no single technology is going to answer the TCT problem. First the chart on your left shows the relative military value on the vertical axis and the response time you have, as a commander to engage that target on the horizontal axis. The time frame of 0 to 72 hours is the generally accepted arena of the TCT. Today's system and planning cycle has no problem handling the problem beyond the 72 hour planning window. On the right, we illustrate 'the long pole in the tent' problem of detection-- on the vertical axis we place the probability of detection with the probability of false alarm on the horizontal axis.. The current capability is shown by the curved line--the capability required to meet the TCT problem is shown by the arrow.

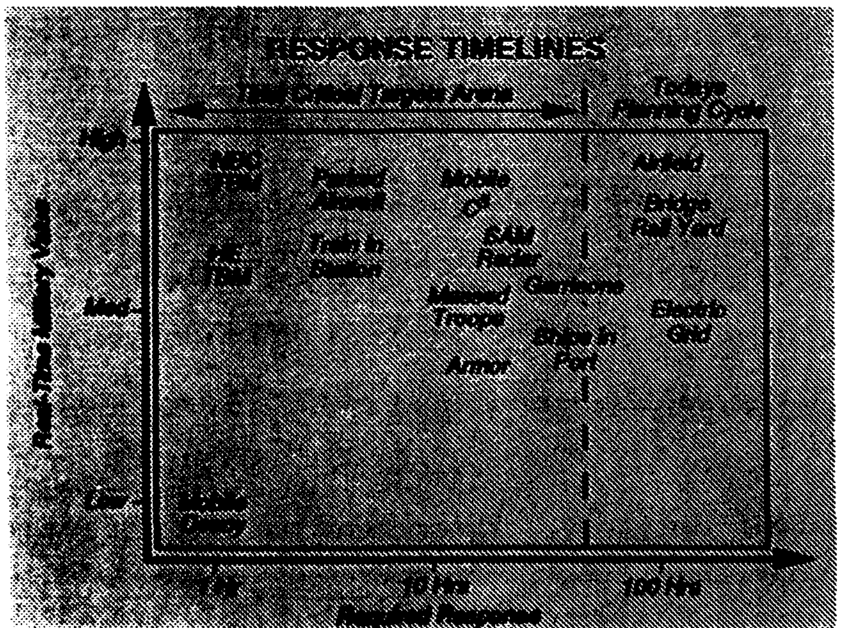
WAR BREAKER

NO SILVER BULLET

ARPA







IMPROVEMENTS :

- **SENSOR COVERAGE RATE**
- **SENSOR EFFECTIVENESS**
- **INTELLIGENCE QUALITY AND TIMELINESS**
- **RAPID AND ADAPTIVE PLANNING**

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SLIDE 9

In the spring of 1991, DARPA began a series of studies to look at potential solutions to the TCT problem as illustrated by the Great SCUD Hunt of Desert Storm. We found that a basic foundation of the required technologies where already being worked in DARPA. The final response was an integrated approach to the problem titled -- WAR BREAKER.

WAR BREAKER GOALS

- DEVELOP/EVALUATE AN INTEGRATED WARFIGHTING CAPABILITY WITH DIRECT PEACETIME APPLICATIONS
- FOCUS IS TO BE ABLE TO EXECUTE SWIFTLY AND DECISIVELY WITH MINIMUM CASUALTIES
- REQUIREMENT IS TO OPERATE AT HIGH PERFORMANCE LEVELS
- PROVIDE CINCs A JOINT, ROBUST CAPABILITY AGAINST WARHEADS OF MASS DESTRUCTION
- DEVELOPMENT EFFORT IS COMPLIMENTARY/ INTEGRATED WITH EVOLUTIONARY SERVICE PROGRAMS

WAR BREAKER OBJECTIVES

DEVELOP AND DEMONSTRATE ADVANCED TECHNOLOGIES AND SYSTEMS SUPPORTING SYNCHRONIZED ACCURATE PROSECUTION OF TIME CRITICAL FIXED AND MOBILE TARGETS (TCTs)

- *Understand Current System Capability and Identify Critical Technology/System Shortfalls*
- *Identify and Focus Development of Key, High Leverage Technology/System Solutions*
- *Incrementally Demonstrate Increasing Levels of Integrated Capability Leading to a Full End-to-End Integrated Live Fire Demo of a "System of Systems"*

ULTIMATELY PROVIDE THE USER DEMONSTRATED CAPABILITIES THAT WILL ENABLE:

- *Rapid Preparation of Battlefield (IPB)*
- *Rapid Command and Control*
- *Rapid Target Detection/Classification and Accurate Geolocation*

SLIDE 12

This slide is a visual depiction of the WAR BREAKER program illustrating the approach of the program and high-lighting the role of the systems engineering process to support the 'systems of systems' solution.

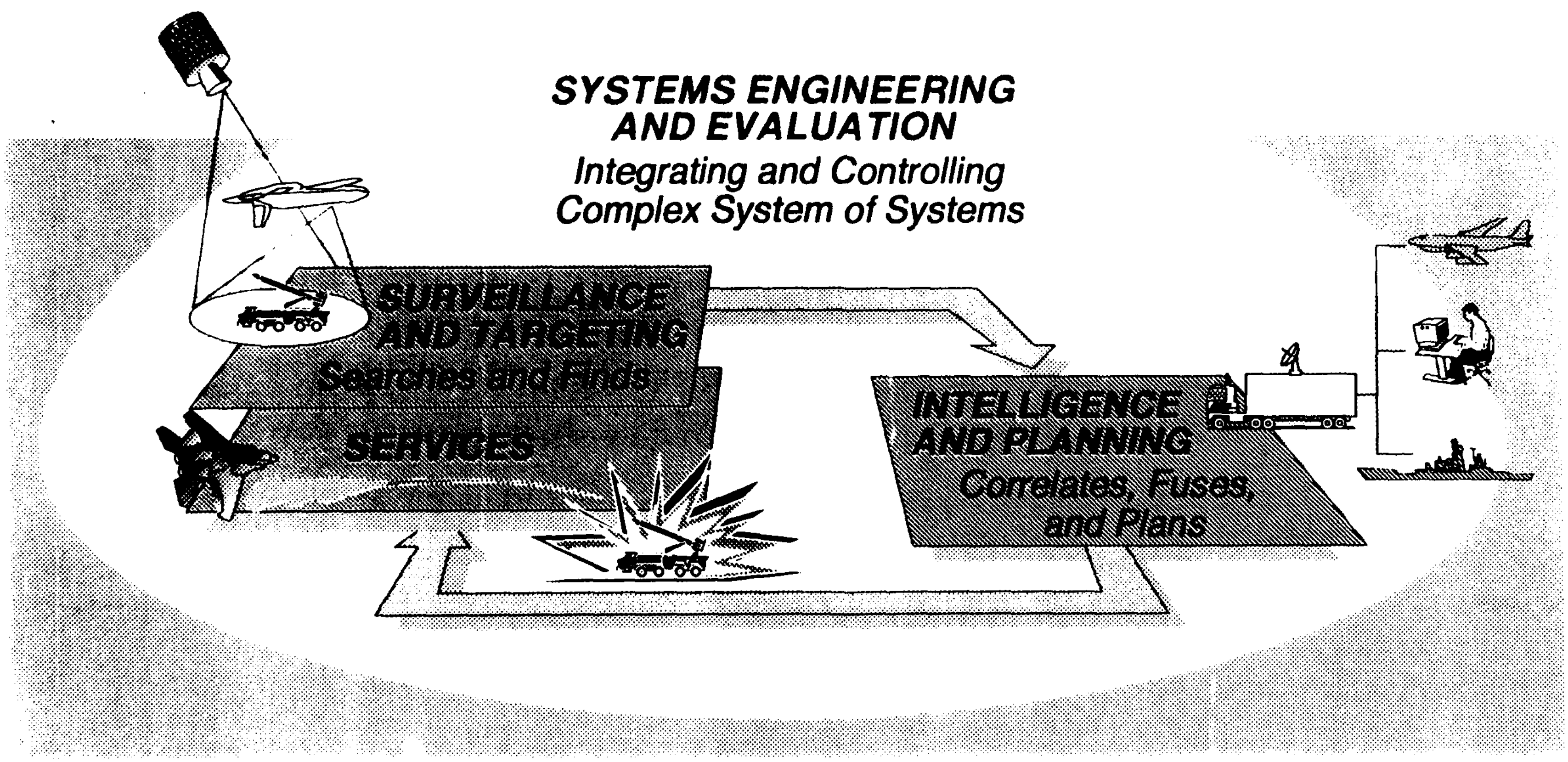
WAR BREAKER MAJOR THRUSTS

- ***SURVEILLANCE AND TARGETING***
  - *Detection/Classification Technologies*
  - *Employ Layered Target Prosecution Systems for Detecting, Classifying and Targeting Fixed and Mobile Time Critical Targets in "Deep Hide"*
  - *Significant Improvements to P_c, P_d at Low False Alarm Rates*
- ***INTELLIGENCE AND PLANNING***
  - *Information Technologies*
  - *Link Intelligence and Operations to Bridge Gap between Sensors and Shooters*
  - *Significant Improvement in Timeliness, Accuracy and Relevance of Information*
- ***SYSTEM ENGINEERING AND EVALUATION***
  - *Integration Processes*
  - *Impose Systems Engineering Discipline on Overall WAR BREAKER Technology/Systems Developments*
  - *Technology/Systems Requirements and Validation*

SLIDE 14

The next three slides will explore those major thrusts in more detail. First the Surveillance and Targeting thrust. The objective is to provide a capability for the rapid detection and classification of TCTs in 'Deep Hide', a particularly challenging proposition. The approach is to develop a layered, integrated network employing existing-and advanced sensors, and the associated advanced sensor processing. The output is to be 1) target detection classification 2) target geo-location 3) terrain and feature data and 4) Battle damage assessment.

TECHNOLOGY AND SYSTEMS SOLUTION TO THE TIME CRITICAL TARGET PROBLEM



SLIDE 13

The major thrusts of the WAR BREAKER program are shown here. First the Surveillance and Targeting thrust focused on the wide area and focused surveillance problem against the 'deep-hide' target. The second area, that of Intelligence and Planning relies heavily on advanced information technologies to improve the timeliness of today's planning and target nomination process. The third thrust is that of the System Engineering and Evaluation program which enforces the required integration processes.

WAR BREAKER

SURVEILLANCE AND TARGETING (S&T)

ARPA

Objective: Provide a Capability for the Rapid Detection and Classification of Time Critical Targets (TCT's), Including "Deep Hide"

Approach: ***Develop a Layered, Integrated Network Employing Existing and Advanced Sensors, and Advanced Sensor Processing to Demonstrate Improvements Commensurate with Targeting and Classification of TCT's in "Deep Hide"***

- ***SURVEILLANCE***
  - *Exploitation of National and Theater Level Sensors*
  - *"Deep Hide" Target Surveillance/RECCE*
  - *Affordable Technologies*
- ***TARGETING***
  - *Autonomous Search and Acquisition of Targets Using State of the Art Sensors*
- ***ADVANCED ALGORITHMS***
  - *Advanced Algorithms and Signal Processing Techniques Maximizing Processing to Support Minimizing Sensor Performance Requirements*

S&T Output:
1) *TARGET DETECTION CLASSIFICATION*
2) *TARGET GEO-LOCATION*
3) *TERRAIN AND FEATURE DATA*
4) *BDA*

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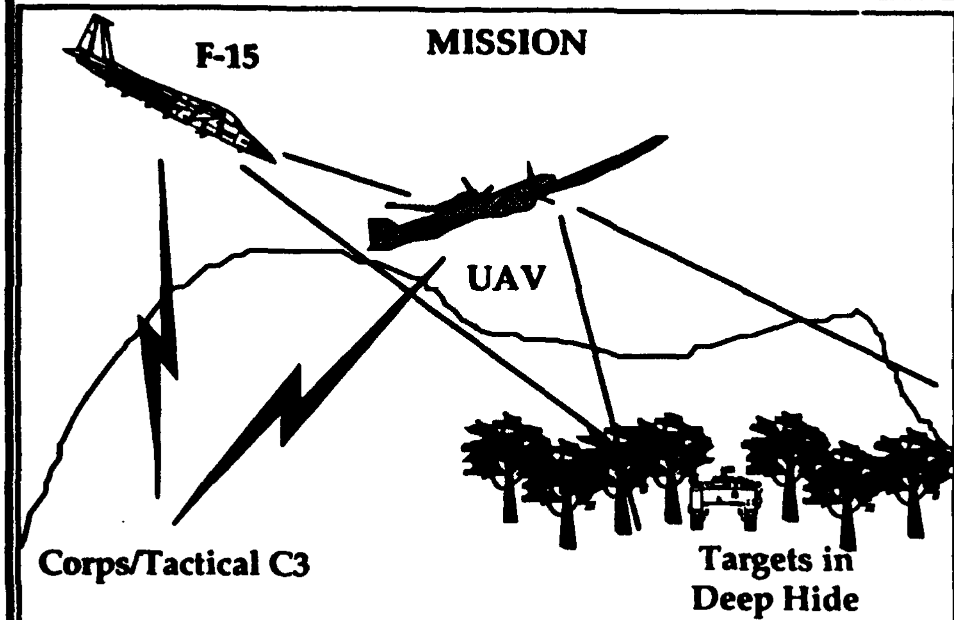
SLIDE 15

The solution doesn't end with TCT detection, we must provide the required linkage and processes to operate within the target cycle time. The Intelligence and Planning Thrust provides that part of the solution by having a program to incrementally automate the targeting/planning cycle. The thrust consists of an intelligence correlation program(IC), a distributed intelligence processing network to provide the connectivity(INTNET), an automated strike planning and description aids system(LAC), and a terrain and feature generator(TFG) to furnish the feedback loop into the theater terrain data base.

TECHNOLOGIES FOR INVESTMENT
LOW COST RADAR

ASTO

MISSION



TECHNICAL OBJECTIVES

- Analyze and Design a Dual-Band SAR for Airborne Applications
  - Ultra-Wideband at Lower Frequencies (e.g., VHF, UHF)
  - Narrow Band Microwave (e.g., X-, Ku-Band)
- Features
  - Low Cost, Easily Manufactured
  - Modular, Lightweight
  - Adverse Weather Operations
  - Near-Real-Time, On Board Target Detection, Recognition, MTI
  - Foliage Penetration for Detection of Deep Hide Targets
- Exploit ARPA Technologies for Low Cost
- Go/No-Go Decision for Development and Test

TECHNICAL APPROACH

- All Solid State Transmitter
  - Multi-Chip Modules (MCMs)
- Advanced Electronics Packaging
  - MMIC/MCMs
- Low Cost, Accurate Motion Compensation/Navigation
  - GPS Guidance Package (GGP)
- Lightweight, Real-Time Signal Processing
  - Embedded HPCC
- Advanced Antenna Structure
  - Integrated Radiating Wing

INTELLIGENCE AND PLANNING (I&P)

- **Objective:** ***Provide Bridge Between Sensors and Shooters to Get Inside TCT Strike Cycle***

Approach: ***Incrementally Automate Targeting/Planning Cycle***

- *INTELLIGENCE CORRELATION (IC)*
  - *Automation of Intelligence Processing and Data Collection*
- *INTELLIGENCE NETWORK (INTNET)*
  - *Distributed Intelligence Processing*
- *LOCAL ATTACK CONTROL (LAC)*
  - *Automated Strike Planning and Description Aids*
- *TERRAIN AND FEATURE GENERATOR (TFG)*
  - *Automated Terrain Data Generation*

I & P Output:
1) ACTIONABLE INTELLIGENCE
2) DISTRIBUTED SITUATIONAL AWARENESS
3) REAL-TIME BATTLE MANAGEMENT
4) SENSOR-DERIVED "MAPS"

SLIDE 16

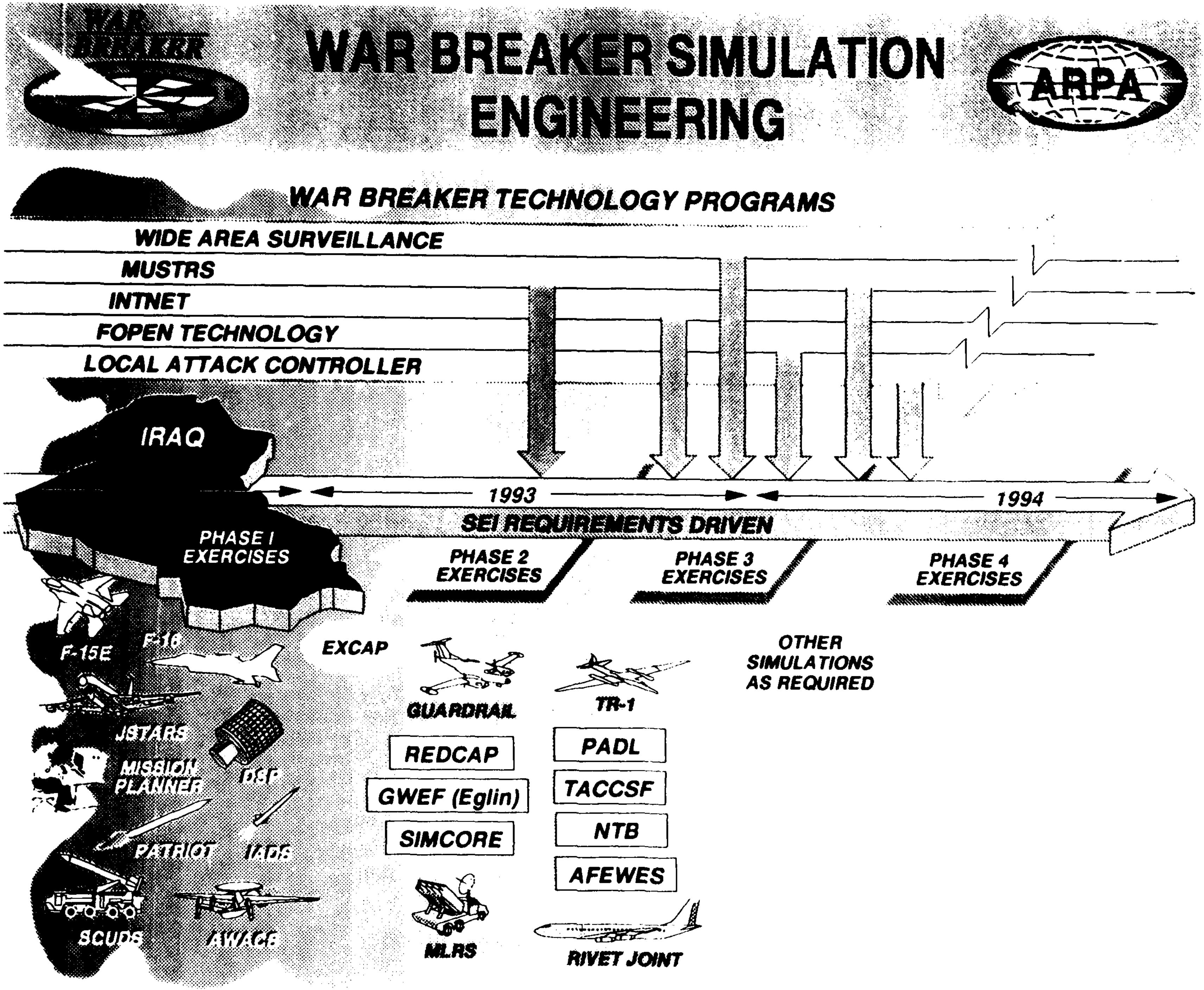
As you have seen the WAR BREAKER program is a 'system of systems' with a broad range of technologies and disciplines. It requires the integration and focus of the third thrust area--system engineering and evaluation(SEE). This thrust has two major parts--first, the System engineering and integration (SEI) program and secondly, the Simulation Engineering and Modeling (SEM) program. The SEI portion enforces systems engineering discipline to maintain focus on development and integration of complex technologies and systems. The SEM program provides system engineering tools necessary for developers and users to understand and evaluate WAR BREAKER capabilities.

WAR BREAKER

SYSTEMS ENGINEERING AND EVALUATION

ARPA

- *OBJECTIVE – ESTABLISH THE TECHNICAL AND SYSTEM LEVEL REQUIREMENTS NECESSARY FOR SOLVING THE TIME-CRITICAL TARGETING PROBLEM*
  - *Evaluate War Breaker Success in Achieving Goals*
- *APPROACH – CREATE A SYSTEMS ENGINEERING ENVIRONMENT ROBUST ENOUGH TO REPRESENT THE END-TO-END AND JOINT NATURE OF THE TCT PROBLEM*
  - *Functional Systems Analysis Tool*
  - *Stochastic Campaign Models*
  - *Engineering Simulations*
  - *MITL/AITL Advanced Distributed Simulation*
- *SEE OUTPUT*
  1) *OBJECTIVE WAR BREAKER OPERATIONAL SYSTEM DEFINITION*
  2) *INDIVIDUAL PROGRAM GOALS/REQUIREMENTS*
  3) *INDIVIDUAL PROGRAM EVALUATION*


WAR BREAKER
WAR BREAKER SIMULATION ENGINEERING
ARPA
WAR BREAKER TECHNOLOGY PROGRAMS
WIDE AREA SURVEILLANCE
MUSTRS
INTNET
FOPEN TECHNOLOGY
LOCAL ATTACK CONTROLLER
IRAQ
1993
1994
SEI REQUIREMENTS DRIVEN
PHASE I EXERCISES
PHASE 2 EXERCISES
PHASE 3 EXERCISES
PHASE 4 EXERCISES
F-15E
F-16
EXCAP
GUARDRAIL
TR-1
OTHER SIMULATIONS AS REQUIRED
JSTARS
MISSION PLANNER
DSP
REDCAP
GWEF (Eglin)
SIMCORE
PADL
TACCSF
NTB
AFEWES
PATRIOT
IADS
SCUDS
AWACS
MLRS
RIVET JOINT

4-5-93

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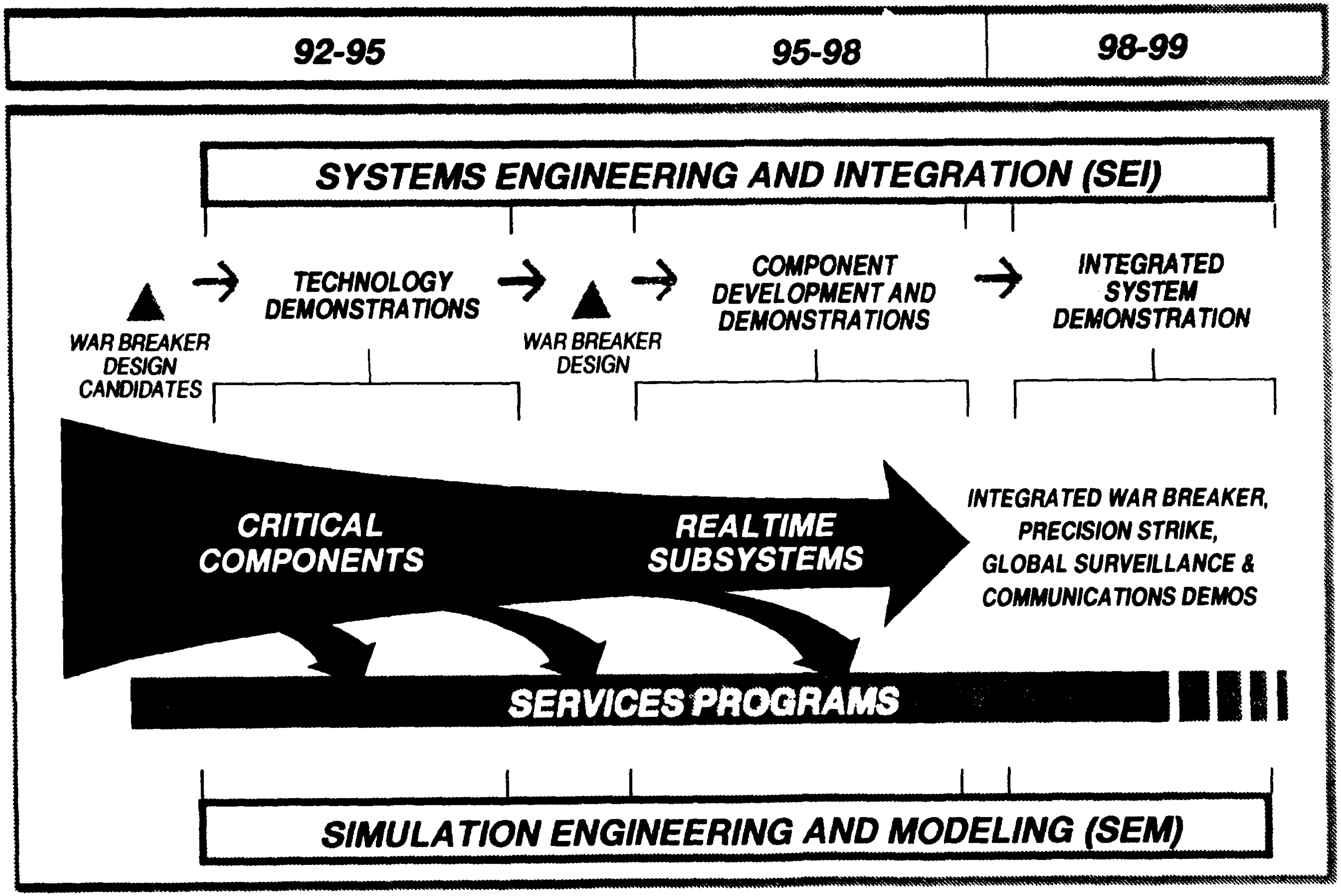
BU SLIDE -- SEE #22

The slide illustrates the actual players involved in the Zealous Pursuit demonstration held in December of last year.

WAR BREAKER IS A PHASED DEVELOPMENT PROGRAM



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BU SLIDE -- S & T #18

This slide is a graphical presentation of the functions you saw demonstrated in the sensor detection of hidden targets tape and the Thirsty Saber video. Both the 'Deep Hide' surveillance and the target acquisition problem are being addressed by the programs listed on this slide.

WAR BREAKER TECHNICAL INVESTMENT AREAS

SURVEILLANCE AND TARGETING

- AUTOMATIC TARGET DETECTION/RECOGNITION ALGORITHMS
- LOW COST, AFFORDABLE RADAR TECHNOLOGY
- FOLIAGE PENETRATION RADAR TECHNOLOGY
- MULTI-SPECTURAL EO/IR
- INTERFEROMETRIC SAR
- INTERNETTED UNATTENDED GROUND SENSORS

INTELLIGENCE AND PLANNING

- INFORMATION CORRELATION/FUSION
- TEXT UNDERSTANDING
- CONTEXTUAL SENSOR EXPLOITATION (UNITS/MOVERS/MAPS)
- DISTRIBUTED MULTIPLE ACCESS DATA BASE
- ADAPTIVE PLANNING TECHNOLOGIES

SYSTEM ENGINEERING AND EVALUATION

- DISTRIBUTED SIMULATION FOR SYSTEMS ENGINEERING

ADVANCED RESEARCH PROJECTS AGENCY
3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

July 15, 1993

MEMORANDUM FOR ASTO - DALY

SUBJECT: Clearance of Paper/Report/Speech for Open Publication

Reference is made to the following material submitted for clearance for open publication:

EVOLVING MILITARY TECHNOLOGY

XXXXX The above referenced material was **CLEARED** for open publication by OASD(PA) on July 14, 1993, Case No. 93-S-2548. All copies should carry the following Distribution Statement "A" as follows: (SEE RECOMMENDED CHANGE ON PAGE 9)

APPROVED FOR PUBLIC RELEASE
DISTRIBUTION UNLIMITED

_____ The above referenced material **WAS NOT CLEARED** for open publication by OASD(PA), Case No. ______. All copies should carry the following Distribution Statement ____ as follows:

G. T. Winn
Technical Information Officer

Attachments

CC: K Pedzone

NEWPORT SCRIPT

Slide 1. Title: Evolving Military Technology

Hello, I'm Judith Daly from ASTO and I am going to talk about evolving military technology particularly as it relates to the payoff associated with situation awareness and battle management. A common theme in the evolving doctrine of all the Armed Services is the ability to rapidly and effectively neutralize enemy forces throughout the depth of a commander's area of responsibility. This requirement applies at every echelon and across the spectrum of conflict from high intensity warfare to military operations other than war (e.g., peace keeping, as we have seen so recently in Somalia). Furthermore, as force structure and weapons procurement continue to shrink over the remainder of the decade, commanders' dependence on a "maneuver by fire" capability will increase given the emphasis on rapid victory with smaller resources achieved with minimal casualties.

See RECOMMENDED change
-p. 9

93-S-2548

Slide 2. Title: Technology Development in a Mission-Driven System Context

Emerging technologies in remote sensing and information processing will provide the linchpin for locating and suppressing threats before unacceptable damage is inflicted on friendly forces. One of ASTO's major goals is to manage what is being referred to as the "military technical revolution" by maturing and integrating within a systems context technology developed elsewhere in ARPA, DOD, and the Intelligence Community so as to facilitate insertion into the evolving deep strike architectures of the Armed Services. Technology development in a system context is a radical departure from the way ARPA in particular and DOD in general have conducted R&D, and it is the key to realizing the Administration's vision of cost savings coupled with continued technological superiority. By treating system engineering as a technology, ASTO is merging science and engineering in an effort to move toward a new R&D paradigm that effectively combines the positive aspects of science and engineering so that revolutionary technology reaches the field much faster than the traditional RDT&E cycle.

Situation awareness comprises a current and accurate view of the battle space for both friendly and enemy forces at the resolution necessary to support operations at any given echelon. This translates functionally into the capability to collect data across the entire electro-magnetic spectrum and process it efficiently to reduce false alarms and produce a manageable flow of detections. Numerous sensor product streams must then be correlated and fused so that an all-source picture of the battle space emerges to support analytical treatment of this data. Analysis can then be performed, turning the sensed data into information.

Battle management consists of taking the actionable intelligence which results from superb situation awareness, merging it with current status of friendly forces, and servicing the enemy target population. Situation awareness provides the critical inputs to the planning process which apportions forces, providing the building blocks for operational control and attack execution sequences. The results of the attack execution provide critical inputs into situation awareness via the BDA cycle.

Clearly, the complexity and time constraints associated with providing situation awareness and battle management capabilities at multiple echelons and throughout the theater of operations require an integrated mix of technologies. Furthermore, without a rigorous definition of the mission focus for situation awareness and battle management, functional

boundaries cannot be specified to the detail required to develop militarily usable technology.

Slide 3. Title: Situation Awareness Supports War Fighting at all Levels

Military commanders have always possessed some type of situation awareness and the variables which have determined its contribution to success in battle are equally immutable: currency and quality. The timeliness and accuracy of situation awareness have always been greatly influenced by the state-of-the-art in information technology (e.g., paper made maps possible; the printing press made cartographic products uniform and wide spread; the micro processor made digital terrain feasible). Current situation awareness capabilities suffer from an awkward mixture of highly automated aspects in some areas and intensely manual processes in others. ASTO has targeted those manual/man power intensive areas for automation as an overarching approach to situation awareness.

Situation awareness consists of three basic components:

1. the physical environment

2. status and disposition of enemy forces

3. status and disposition of friendly forces

Sensing and processing provide the basic data for physical environment and enemy status and disposition. While sensors are the most highly automated component of situation awareness, their product is frequently tailored for human exploitation and they are not optimized to defeat enemy camouflage, concealment, and deception techniques. Processing of sensor product is currently a major bottleneck in terms of infrastructure (e.g., digital terrain), and current intelligence (e.g., targeting).

Correlation and analysis utilize the product of sensing and processing to produce the status and disposition of enemy forces. The status and disposition of friendly forces does not have to be sensed and process per se, but the message streams containing the data must be correlated and fused with the physical environment and the enemy status and disposition in order to have genuine situation awareness. On both the friendly and enemy side correlation and analysis remain very manpower intensive. Correlation, outside of specialized technical disciplines such as ELINT, consists essentially of data visualization tools. Genuine automated analysis has yet to escape laboratory settings due to difficulties associated with scaling up from proof-of-concept to operational settings.

Slide 4. Title: Layered approach to sensing and processing

Multi-echelon situation awareness requires layered sensing and processing approach wherein sensors positioned from geosynchronous orbit to the surface of the Earth contribute their products as appropriate. This approach holds the key to disparate situation awareness problems ranging from wide area target nomination to the monitoring of the proliferation of weapons of mass destruction. For each layer ASTO is focusing on different technical payoffs. ATR technology is being developed to eliminate the processing bottlenecks caused by the deluge of product created by National Technical Means. New sensors are being developed for the theater commander which will increase the timeliness and coverage of the battle space, and provide leverage against hidden and/or camouflaged targets (e.g., FOPEN). ATR, advanced avionics, and mission management software are being combined to produce a family of autonomous, target-seeking weapons platforms. Finally, unattended ground sensor technology is being developed to augment both manned and unmanned missions against a wide array of targets across the entire spectrum of conflict.

Slide 5. Title: Targets in Clutter

ASTO is striving to automate sensor product processing to the greatest extent feasible. The next to slides illustrate the concept of operations guiding the development and integration of sensing and processing for situation awareness. New sensor types such as ultra wide band radar can be employed to pull targets out of clutter using the capabilities of the sensor and advanced processing techniques. Here we see a truck in a dense foliage environment. Using the layered approach described on the previous slide, multiple sensors will produce streams of target detections over various amounts of real estate at varying resolutions. This "ATRINT" will be a key building block in ASTO's situation awareness system construct.

Slide 6. Title: IES Processing

ATR technology is not only applicable at the vehicle level, but is also being applied at the unit and force level. This slide depicts a processing sequence by the Imagery Exploitation System (IES). IES is essentially a unit level ATR which operates above the image plane to refine the target detection stream coming form the various sensors. By merging sensor product with terrain and doctrinal knowledge IES can infer the existence and type of units. ASTO is also developing ATR technology for MTI radar which would use the MTI track file history in conjunction with terrain and motion domain to locate and identify vehicles and units on the move.

Slide 7. Correlation and Fusion

The challenge of correlation and fusion is one of amalgamating and reconciling numerous and varied sensor product streams in near-real time. In-puts will range from manual exploitation reports to machine generated detections to transmissions from unattended ground sensors or human observers. The first major technical hurdle which ASTO has targeted in this area is the extraction of essential information from various media and formats and the instantiation of all sensor product processing into a single uniform representation for machine processing. Following this step the technology must remove duplicative data, and normalize all sensor bias and error to ensure accurate correlation of single intelligence disciplines followed by fusion of multi-source data so that all inputs to analytical processes have a single coordinate system, uniform random error representation, and reflect the strengths and weaknesses associated with the sensor product which was merged to create the fused and correlated detection.

Slide 8. Automated Analysis

Up to now we have been dealing with data (albeit, data enhanced by specialized processing and rigorous comparison with temporally and spatially coincident data from other sources). Analysis turns data into the information which underpins situation awareness. ASTO is developing automated analytical routines within the mission/system context of two critical problem areas in the evolving international security environment: destruction of time critical targets (WAR BREAKER) and monitoring, tracking, and interdicting weapons of mass destruction and their means of delivery (CPI). This slide is an example from the WAR BREAKER program depicting the effort to automate labor-intensive and time consuming aspects of the targeting process.

- Terrain analysis: currently undertaken with out-dated hard copy cartographic products, acetate overlays, and felt-tip pins can be accomplished orders of magnitude faster utilizing current digital terrain and parallel processors.

- Target location projection: currently an entirely manual process operating hours and days behind the intelligence data can be accelerated orders of magnitude using advanced temporal tracking algorithms and parallel processors allowing friendly forces to operate inside enemy strike cycles.

- Force structure analysis: Current order of battle is maintained by a cell of human analysts working with office automation and rudimentary data visualization tools. Rather than performing an analytical function, these highly trained individuals are in effect data slaves providing their superiors with electronic paper. Automated force status assessment, based on parallel implementation of rule based systems for inferring military hierarchies will free up scarce analytical resources creating a far more efficient machine-human division of labor.

- Battle damage assessment: Currently more of an art than a science. Advanced correlation and fusion techniques can free up human analytical resources for the more difficult decisions based on BDA information such as determining combat effectiveness of an attacked unit or restrike decisions, rather than have them relegated as they are now to sifting and comparing reports.

Slide 9. Title: Battle Management Technology

The basic enabling technology for battle management which ASTO is developing is distributed graphic and persistent object bases. This chart depicts the (notional) information aggregation and interaction processes within the "shared ontology" made possible by this technology. Each echelon would have access to its own positional and situation awareness information, as well as any information passed from higher echelons. Any commander would see all levels below him and could grant subordinates access to his situation awareness graphics and persistent object bases. These graphics and object bases would represent varying types of information including movement indicators and command information. Lower echelons would be simpler and less capable due to the tactical nature of their missions. Higher level of command would have increasing capabilities, such as those shown at the bottom right. Enemy units could be identified for additional intelligence collection focus. Friendly unit movements could be projected forward in time based on terrain trafficabililty, mission profile, logistical considerations (e.g., fuel availability). Logistics needs could be assessed and projected to support the establishment of resupply points. Finally, staff planning could be supported by simulating projected engagements to generate options and help establish likely outcomes.

This capability depends upon the ability to communicate in an agile and effective manner between and among all relevant echelons in a rapidly evolving battle space. Depicted on the right of the chart are principal existing Army communications systems at various levels of command. These systems have various degrees of connectivity; some connections are automated and some are manual. In addition, SINGARS systems, though compatible, are formed into networks which require gateways in order to connect with one another. This complex structure of interconnections can result in significant delays in passing information up and down the chain of command. The diagonal rectangle on the right of the graphic portrays ASTO's concept for an adjunct communications pipeline that addresses the need for increased timeliness, through-put and connectivity. This system will not replace any existing systems, but will supplement their capabilities to provide increased timeliness and through-put. In addition, because it is connected to individual troops and vehicles at the lowest level, it can pass position and status data from friendly units upward, and to pass intelligence and command data downward. This can be aggregated into unified, distributed object bases at each echelon. Such repositories of current and accurate information tailored to the missions associated with each echelon is the linchpin for concepts like "virtual weapon"

RECOMMEND

* might also be worth mentioning term SINCGARS means "Single Channel Ground & Airborne Radio System".

wherein individual soldiers or unmanned air, land, or sea vehicles can pull the lanyard for indirect fire weapons located tens or hundreds of kilometers to the rear. in summary, superb situation awareness enables real-time battlement, allowing the realization of concepts such as "virtual weapon" which are critical to evolving military doctrine like 360 Degree Deep Battle.

Slide 10. Title: Mission/System Context

Now I want to shift gears and talk about ASTO's technology investment strategy, which will guide the selection of individual technical approached in the pursuit of the capabilities I just described. The Mission/system context is critical in defining and limiting the parameters of technical investigation. I will illustrate this in the context of two major national security issues: 1) the monitoring, assessment, and interdiction of weapons of mass destruction known in DOD as the Counter-Proliferation Initiative (CPI) 2) the location and destruction of time critical targets, which is the underlying goal of the ARPA WAR BREAKER Program. The context informing technology development in both these programs is an interrelated continuum involving U.S. counter-proliferation activity starting with warning and ending in open hostilities. The population of potential ARPA customers play across this continuum depending upon the intersection of U.S. policy and the behavior of potential adversaries. Depending upon what portions of the ARPA customer population are involved in a given stage of U.S./Adversary interaction, relative emphasis can be given to the utility of different kinds of ARPA technology. This technology, in turn, will enable the generation of a wide range of response options tailored to threat and appropriate to the requirements of the policy community at any given stage in a proliferation sequence.

Slide 11. Title: Technology Payoff Identification

Utilizing the Mission/System context, we can then develop a rigorous methodology for identifying areas of technical payoff leading to technology investment. Think of this rectangle overlaid on the mission/system context as a core sample through the many layers of WMD proliferation continuum. The results are a data point containing the answers to the questions of what (warning), who (intelligence community), how (sensors), why (acquire components), with what (diplomacy). Multiple core samples can then be plotted in a 3-D representation that maps customer/adversary activity/technology. This mapping directly informs ASTO's technology selection approach, by facilitating a series of selected system trades. The bottom right hand corner of the graphic is an example of this process with respect to amount collected versus specificity of processed information required to enhance current capability such that improvement captures two specific end point situations: 1) wherein warning of WMD proliferation activity is revealed by sifting massive volumes of low information content data, and 2) where direct evidence of WMD capability is gathered by targeting collection against what would in all probability be a highly camouflaged event. The trade-offs between negotiating the ocean of WMD related data, and pin pointing a smoking gun situation with highly tailored technology lead to determination of the system parameters that will inform the ASTO technology investment strategy.

Slide 12. Title: WAR BREAKER System Context

This slide is an example of the next step in the process taken from the WAR BREAKER program. Once system trades are accomplished, a detailed system context can be completed to serve as the frame work for technology development. The WAR BREAKER system context is the result of working through an exhaustive set of trades wherein technology is linked to the peace-crisis-war continuum and balances are struck between situation awareness-related technology at the national and theater levels vs. battle management-related technology at various echelons leading ultimately to a kill chain which feeds back results of both collection and lethal targeting into the intelligence and planning processes at the appropriate echelon to effect decisions ranging from immediate restrike to alteration of the campaign plan.

Slide 13. Situation Awareness Must be Tailored to Mission/System

It is critical, however, to maintain a direct mapping from the system context to the mission parameters for any given technology development effort. This is a major sanity check employed by ASTO for all evolving military technology resulting from our investment strategy. This slide is an example concerning situation awareness as it relates to WAR BREAKER and CPI. As you can see with respect to underlying goals, customer population, functionality, temporal parameters, level of automation, domain, and analytical approach, the specific technology required to achieve situation awareness for these two programs are in fact very different. Indeed, the process that defines the differences is crucial not only in eliminating redundancy and focusing the correct technical solution on the correct problem space, but it is also a process wherein different technology can be developed to yield mutually supporting capabilities for the merged customer community. In other words, the technologies yielding situation awareness for the CPI Program will establish a precursor level of understanding that will support the execution of WAR BREAKER capabilities if they are required to suppress WMD system which reach adversary force structures despite our efforts to interdict them.

Slide 14. Situation Awareness and Battle Management Combine Synergisticly

Finally, for those of you who have patiently sat through the torrent of words in hopeful anticipation of a quantitative definition of situation awareness and battle management here it is:

You simply take the sum of all possible situations, combine it with the area contained in the battle space and divide it by the constantly decreasing amount of time available and you get the probability of victory.

Tsun-Zu, Jomini, Clausewitz eat your hearts out!!

Seriously, the last point I wan to make is that we mean what we say about no single silver bullet. The power of the emerging information processing technology to shape the battle field of the future lies in its integrated employment. Piecemeal application of situation awareness, no matter how superb will not kill or neutralize anything unless actionable intelligence can be turned rapidly into concrete missions with the right weapons and sensors assigned to the right set of targets. Nor will the most brilliant weapons achieve an effective kill ratio against what will in all likelihood be a numerically superior enemy deployed in a battle space lacking the familiar demarcations of front and rear, unless those weapons are employed using the leverage provided by superb situation awareness.

Thank you very much. Are there any questions?

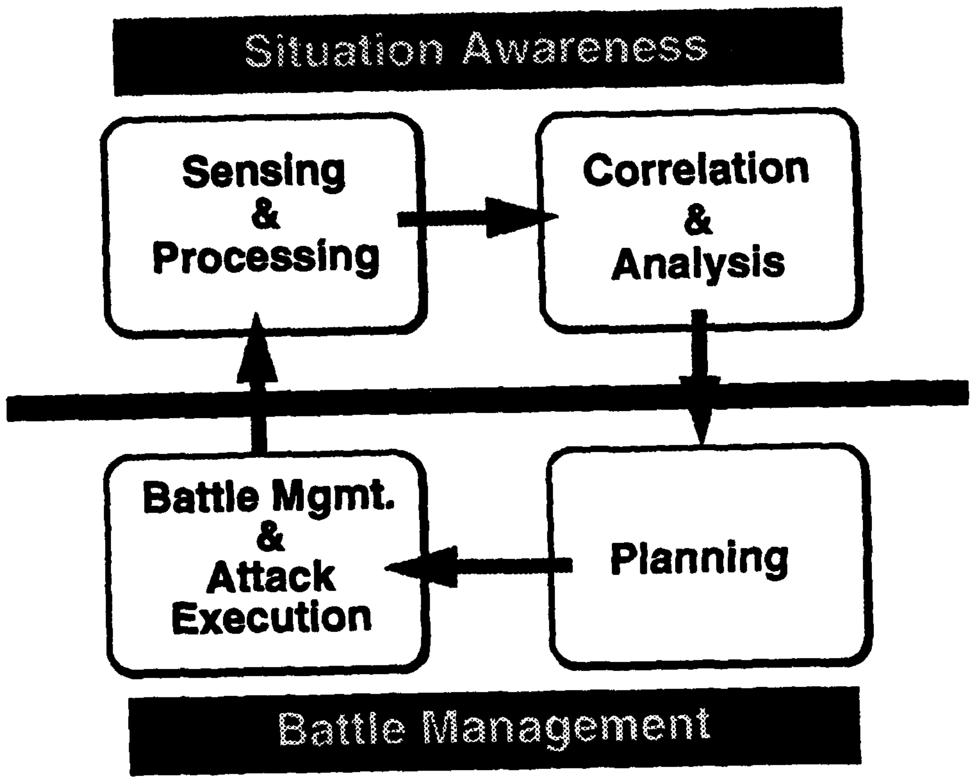
Evolving Military Technology

Presented by:

Dr. Judith A. Daly

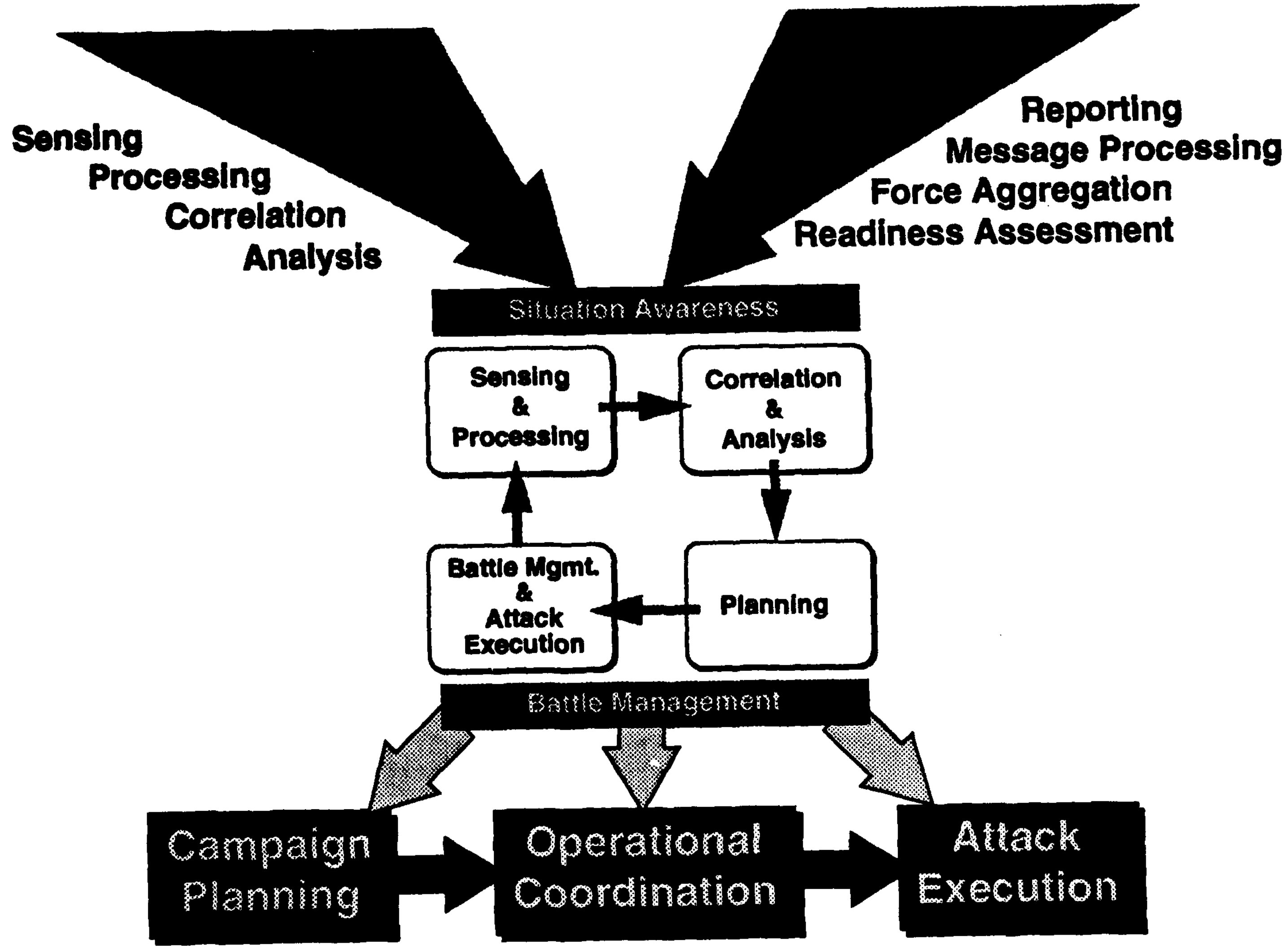
Assistant Director (Acting)
Intelligence & Targeting Division
Advanced Systems Technology Office
Advanced Research Projects Agency

Technology Development in a Mission Driven System Context



No Silver Bullet: Technology must be Integrated
Mission Focus: System Boundaries must be Identified

Situation Awareness Supports Warfighting At All Levels



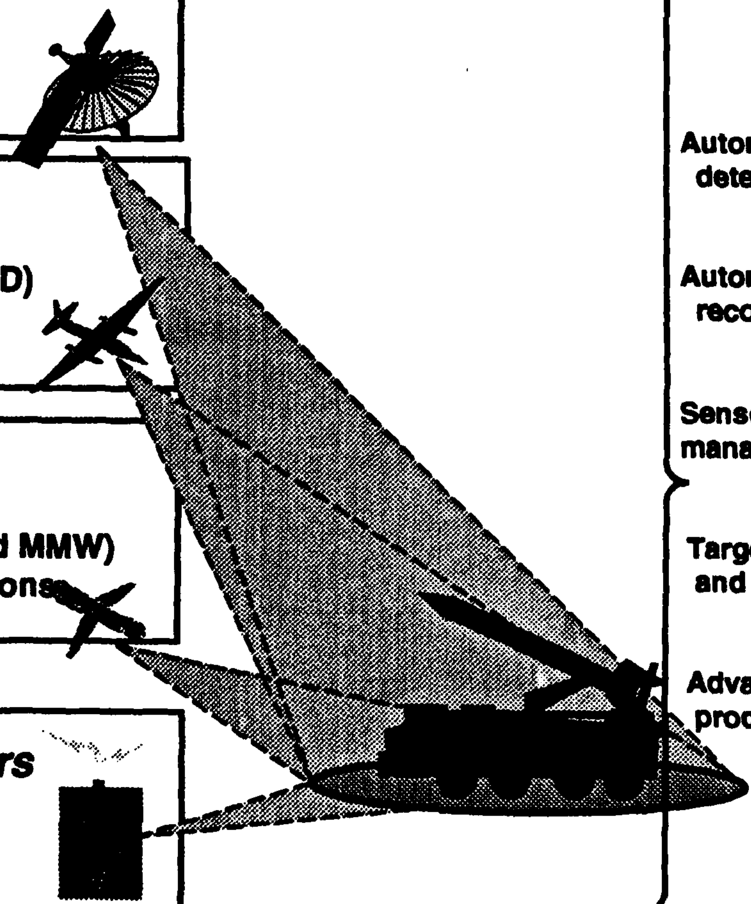
Layered Approach to Sensing and Processing

Global Surveillance
- Existing systems

Theater Surveillance
- "Deep hide" objective
- Multi-mode SAR (FOPEN, MTI, 3-D)
- Advanced IR
- Increased coverage

Targeting
- Robust classification objective
- Advanced sensor suite (FLIR and MMW)
- Manned and unmanned applications

Unattended Ground Sensors
- Extended range sensors
- Auto detect and report



Automatic target detection

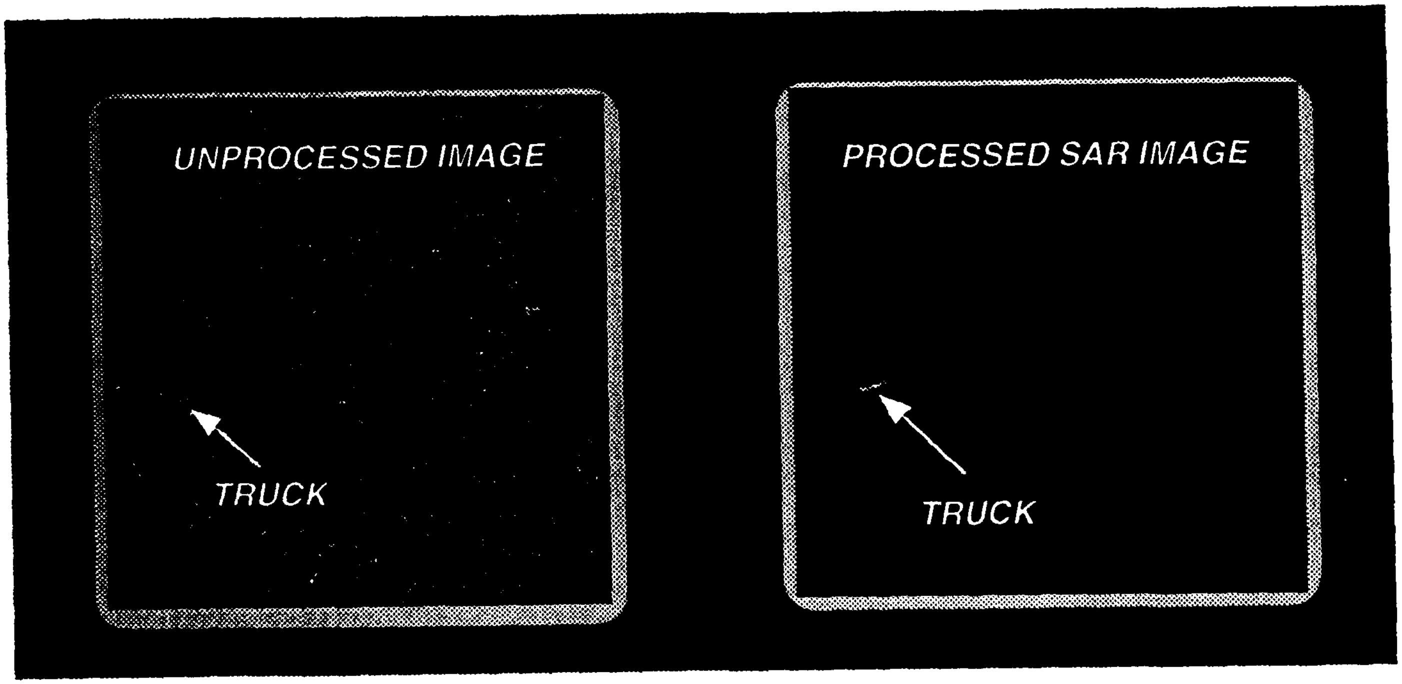
Automatic target recognition

Sensor management

Target signatures and phenomenology

Advanced processors

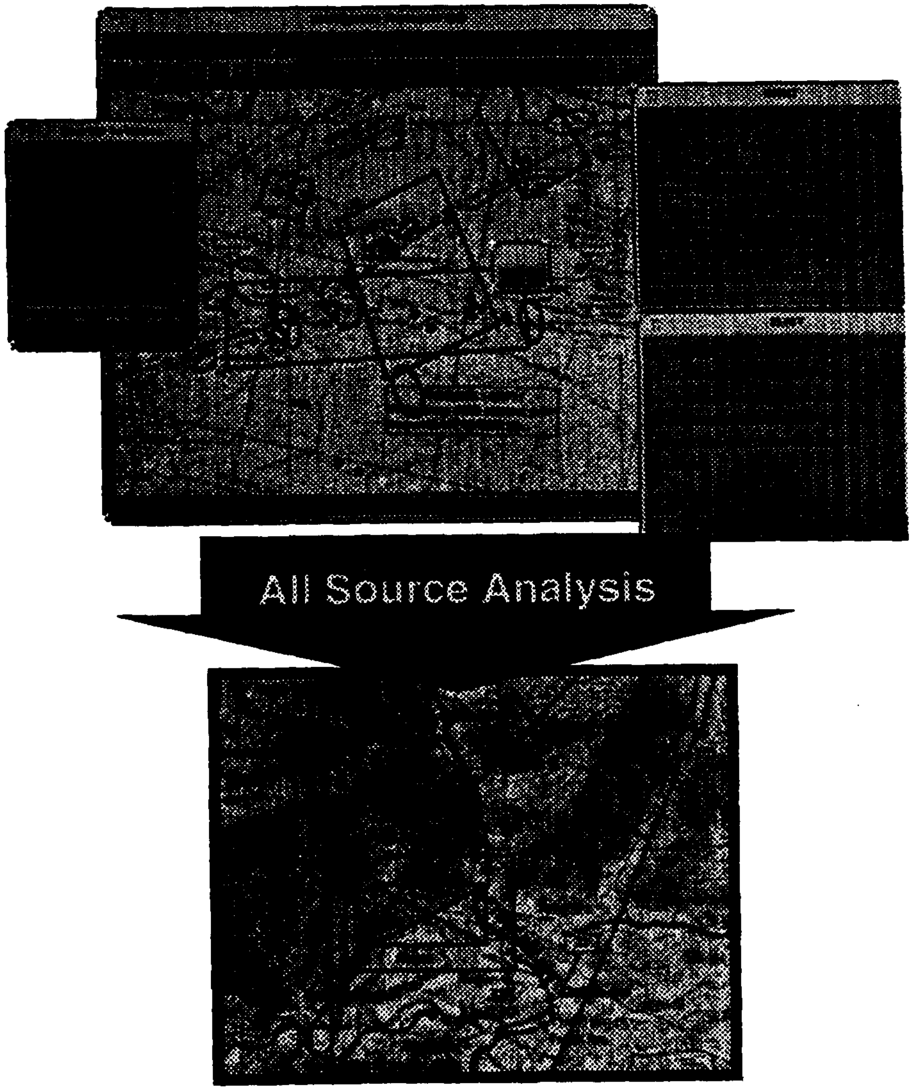
Targets In Clutter



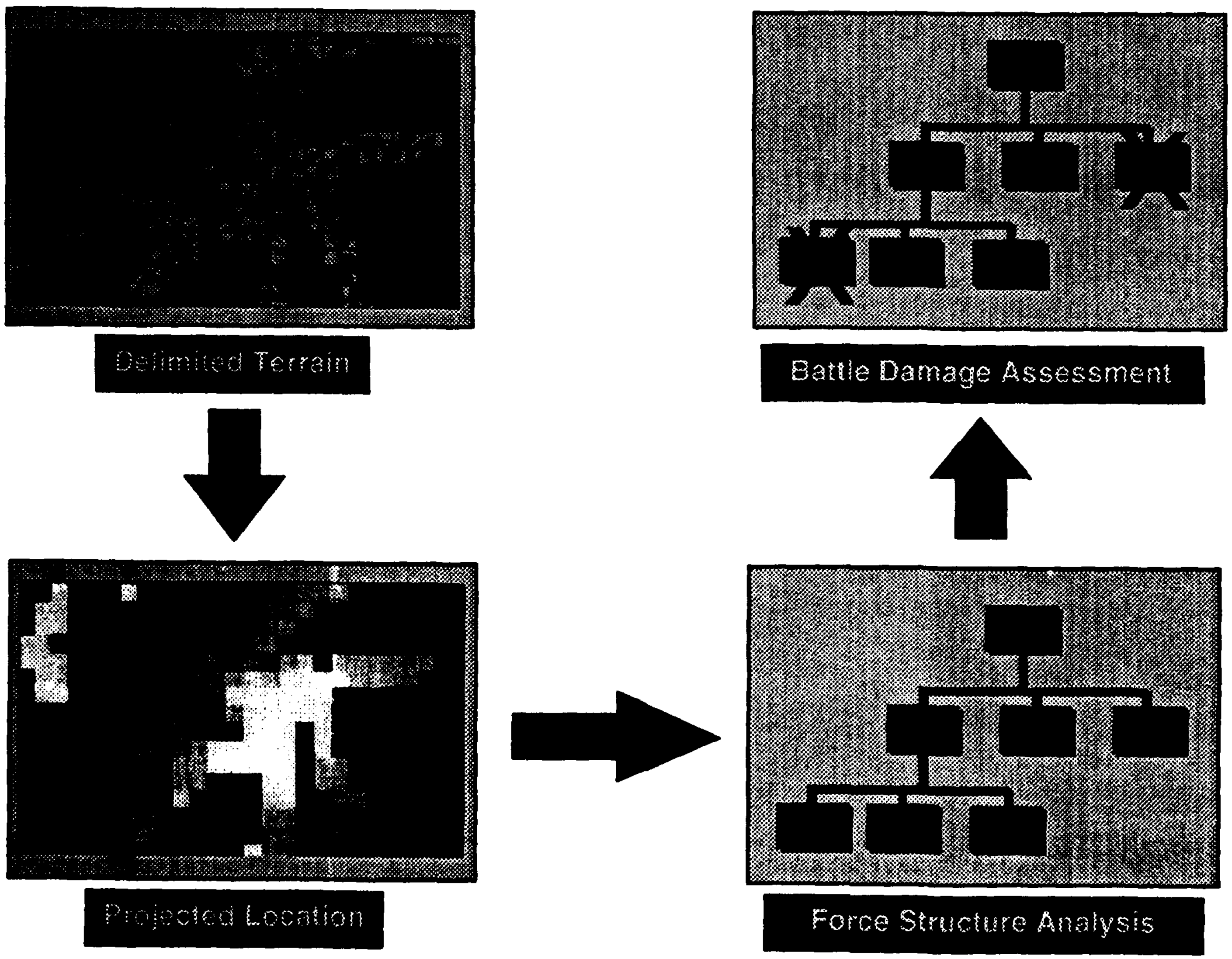
UWB Image

Truck Located

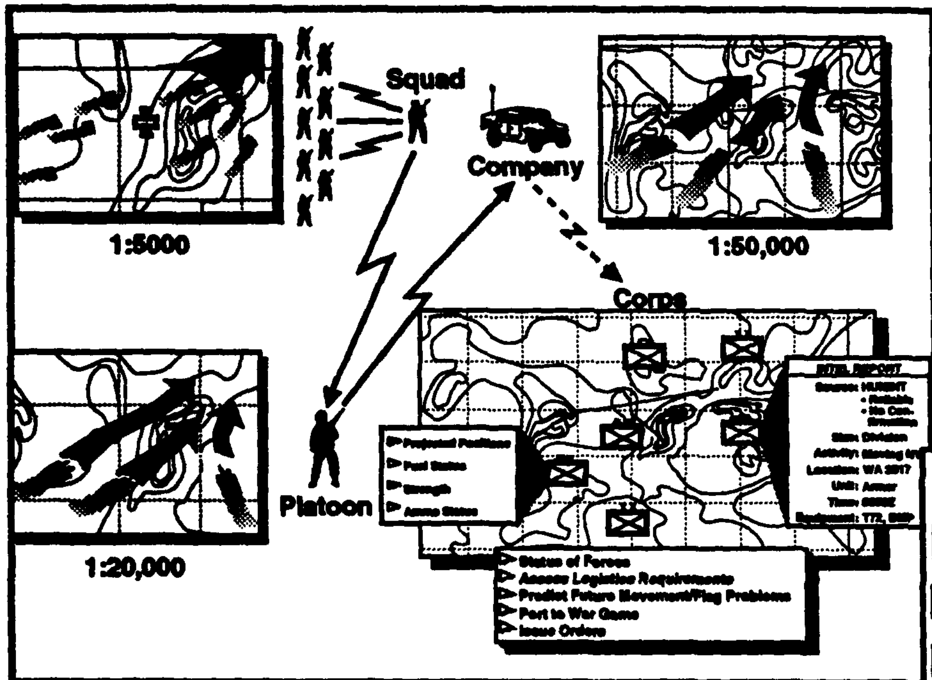
Correlation and Fusion



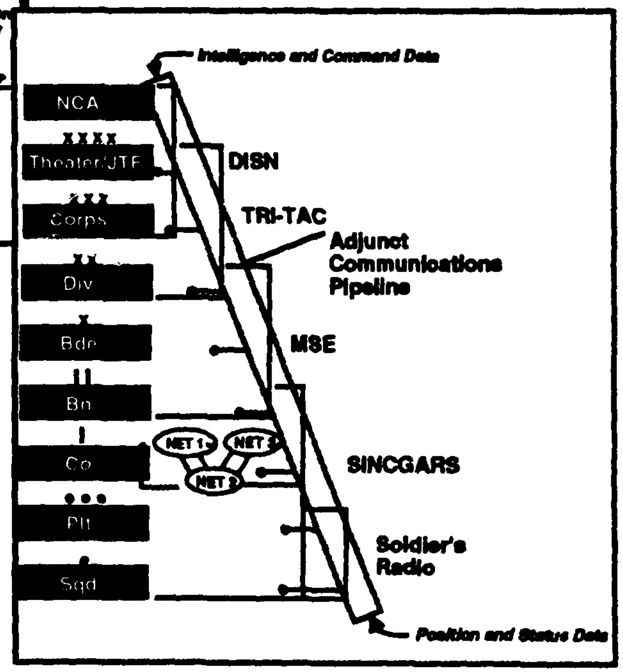
Automated Analysis



Battle Management Support Technologies

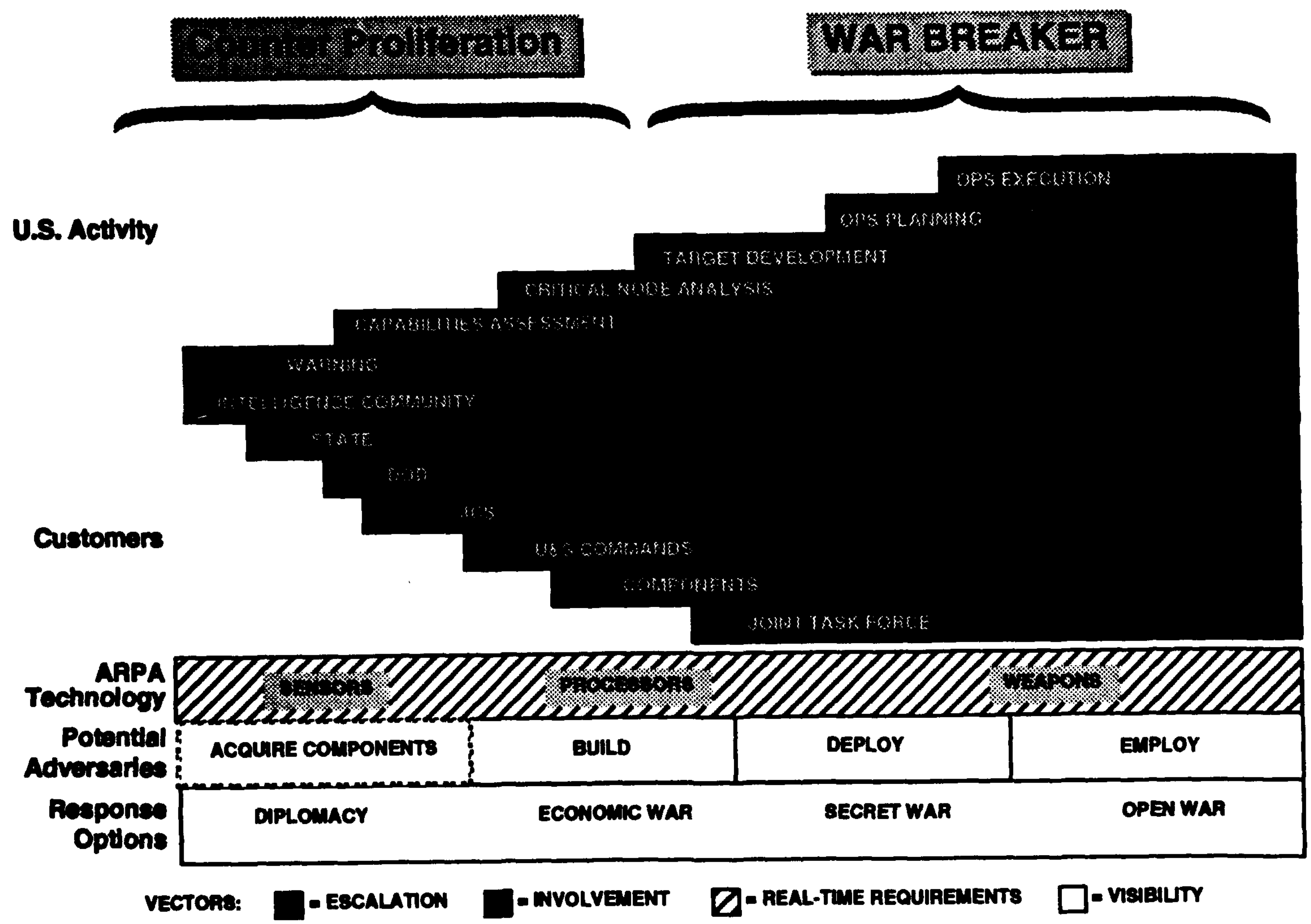


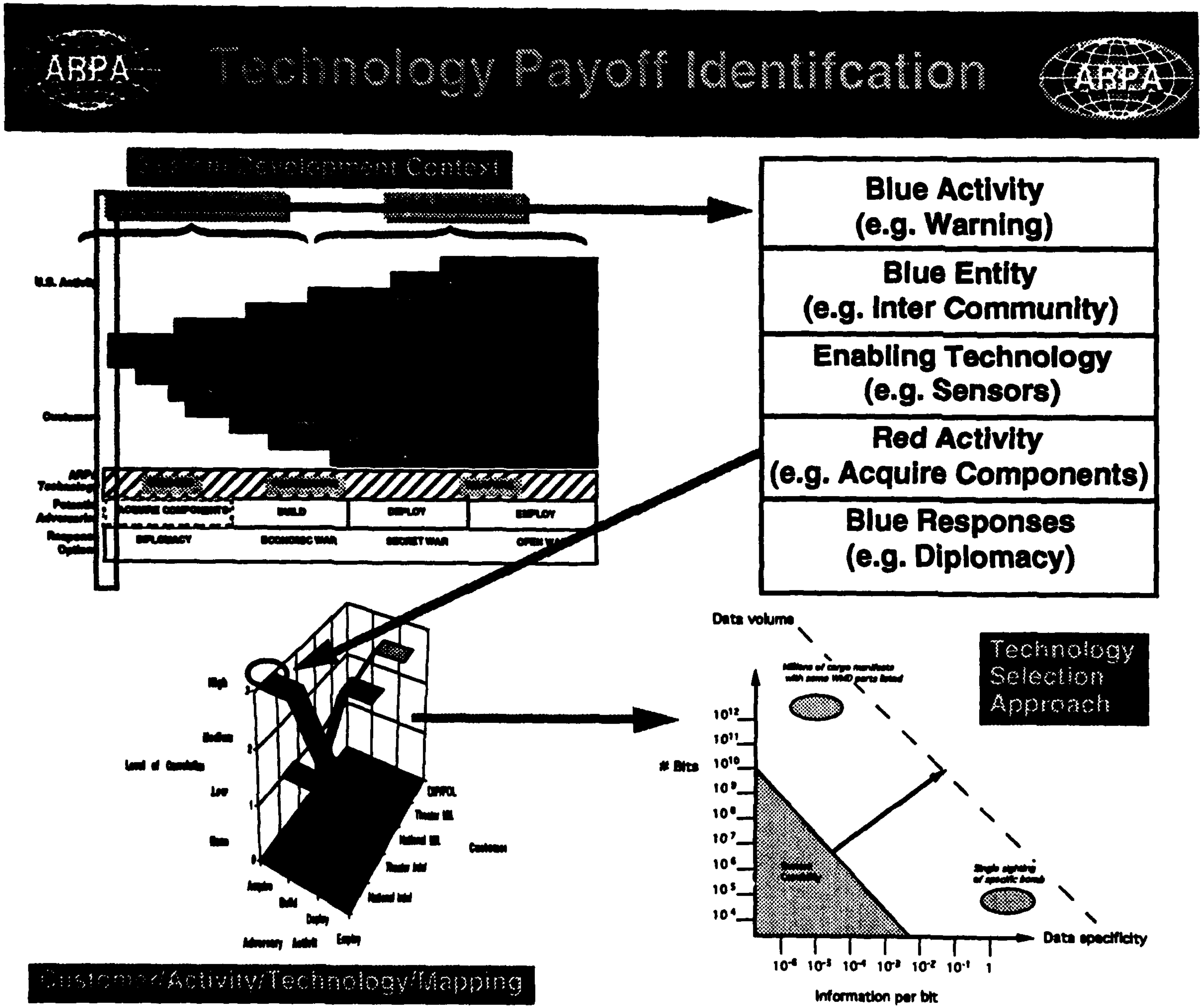
Visualization and Planning



Integrated Communication

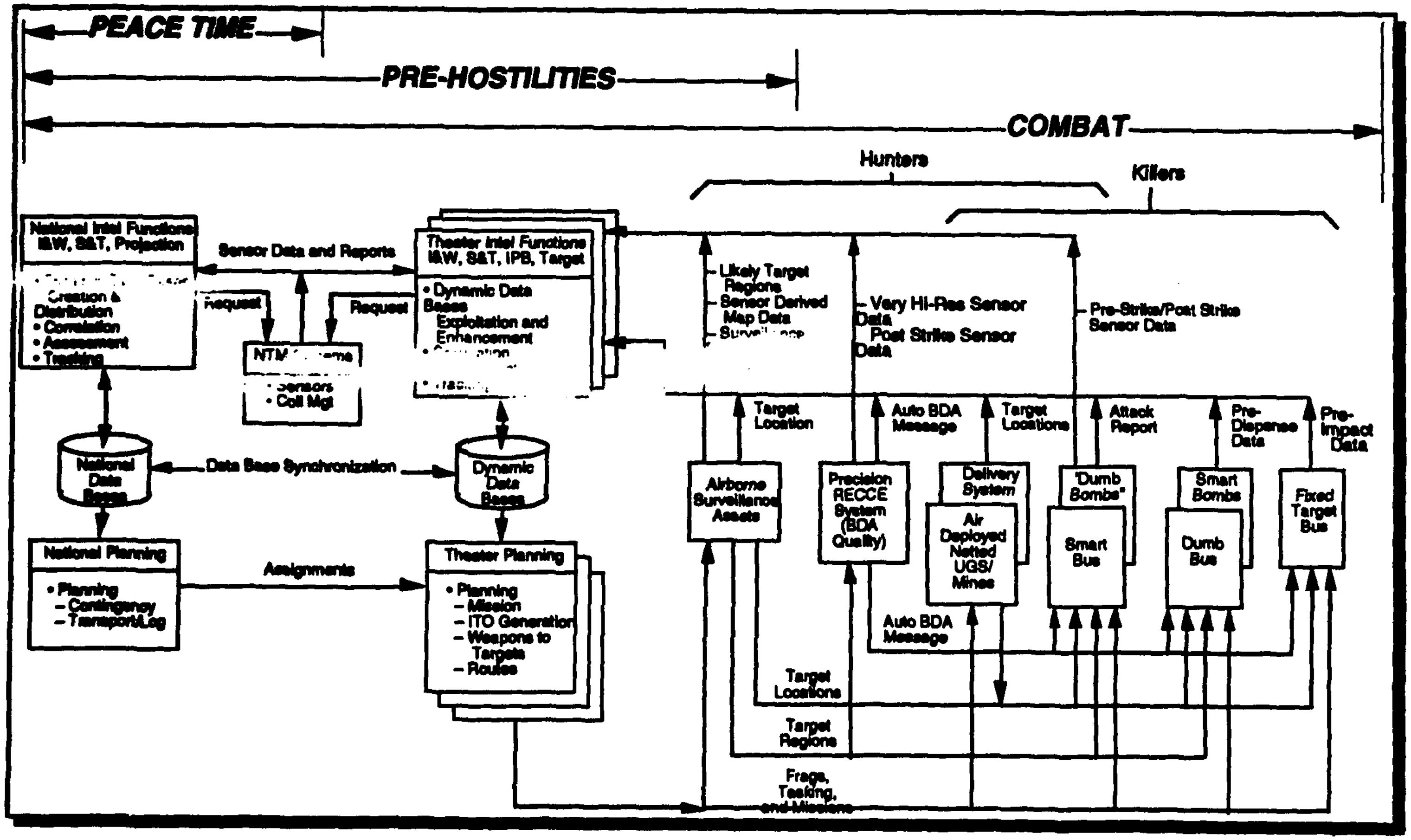
Mission/System Context





ARPA
Technology Payoff Identifcation
ARPA
Blue Activity (e.g. Warning)
Blue Entity (e.g. Inter Community)
Enabling Technology (e.g. Sensors)
Red Activity (e.g. Acquire Components)
Blue Responses (e.g. Diplomacy)
ACQUIRE COMPONENTS
BUILD
DEPLOY
EMPLOY
DIPLOMACY
ECONOMIC WAR
SECRET WAR
High
Medium
Low
None
Level of Capability
Acquire
Build
Deploy
Employ
Adversary Activity
Customer
Data volume
Bits
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
Data specificity
10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1
Information per bit
Technology Selection Approach
Customer/Activity/Technology/Mapping

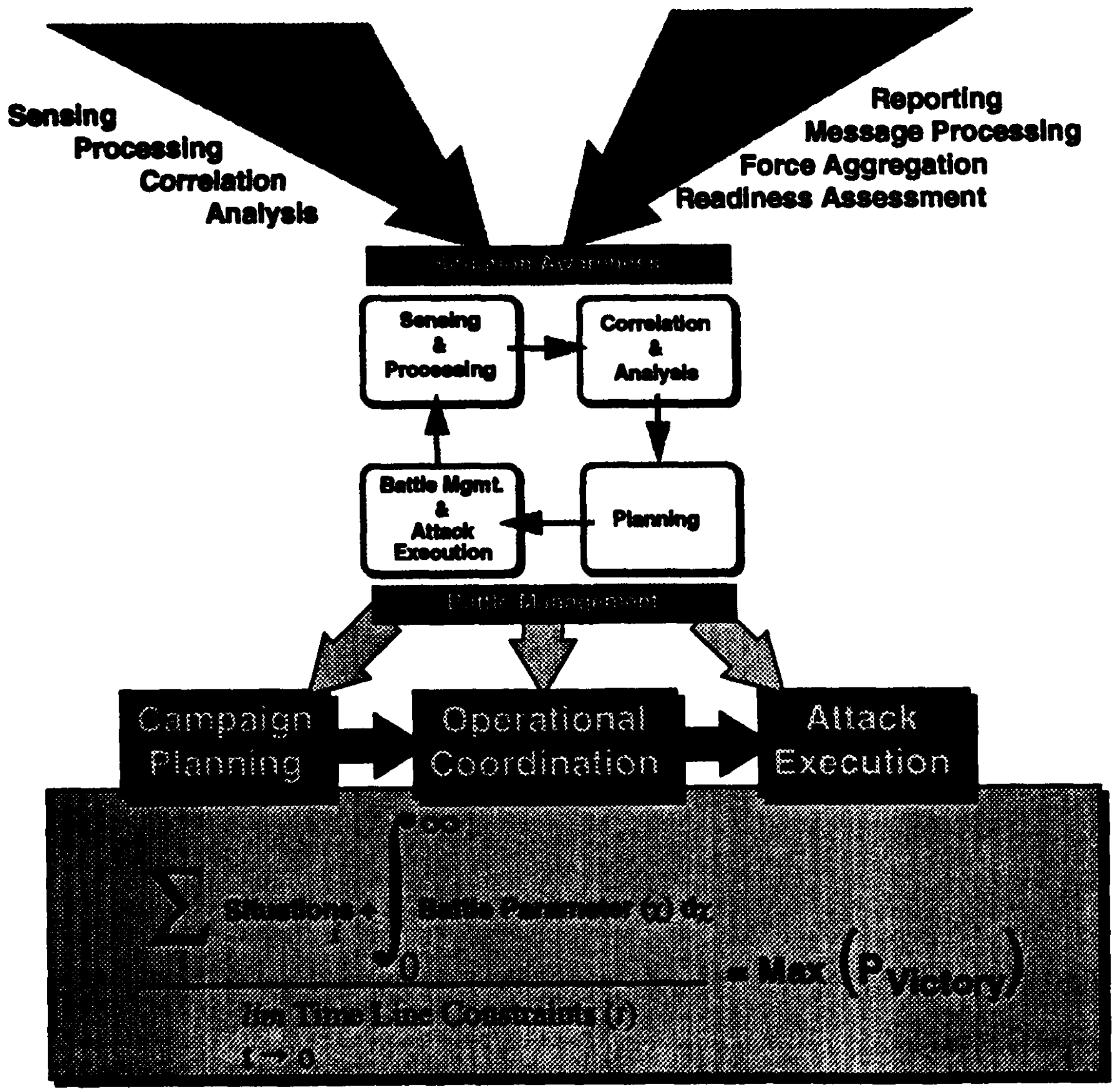
WARBREAKER System Context



Situation Awareness Must Be Tailored to Mission/System

	WARBREAKER	Counter Proliferation
Goal	Get inside enemy cycle times	Support detection, monitoring and interdiction of WMD proliferation
Customers	Services, CINCs,JTF CMDRs	Diplomatic, intelligence, arms control, policy communities
Functions	*Support to targeting*	I&W, capability assessment, support to critical node analysis and response option generation
Time Frame	Days, hours, minutes	Years, months, weeks
Processing Paradigm	Full automation	Human-computer system
Dominant Target Feature	Mobility	Fixed and mobile mix
Intentions Analysis	Peripheral (Relatively easy)	Central (Difficult)

Situation Awareness and Battle Management Combine Synergisticly



Evolving Military Technology

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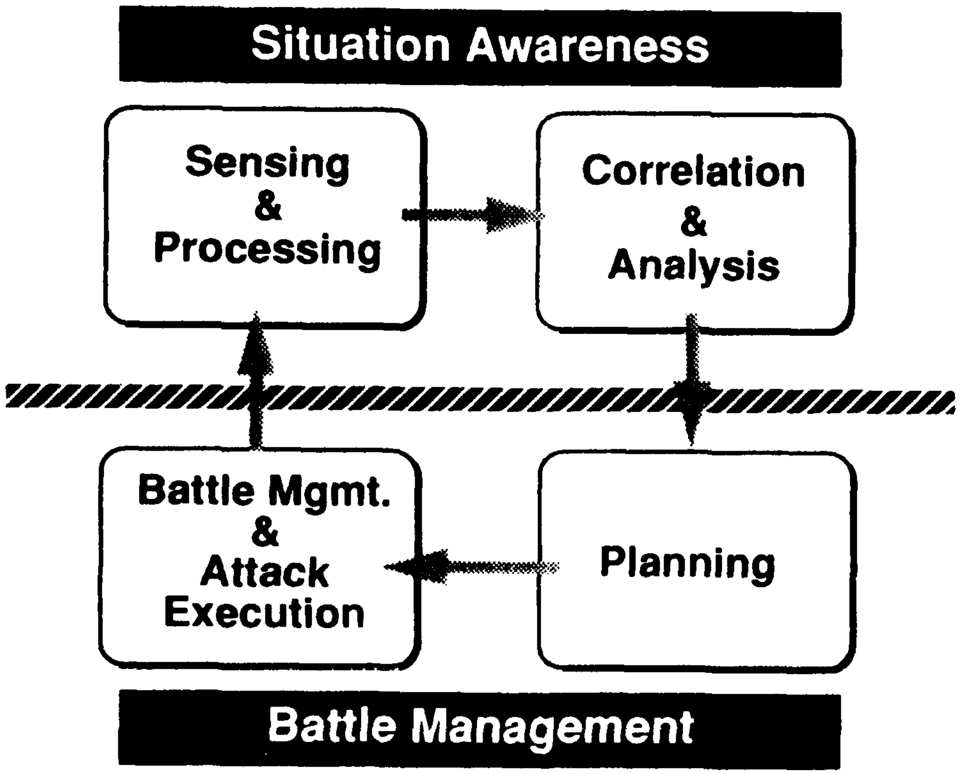

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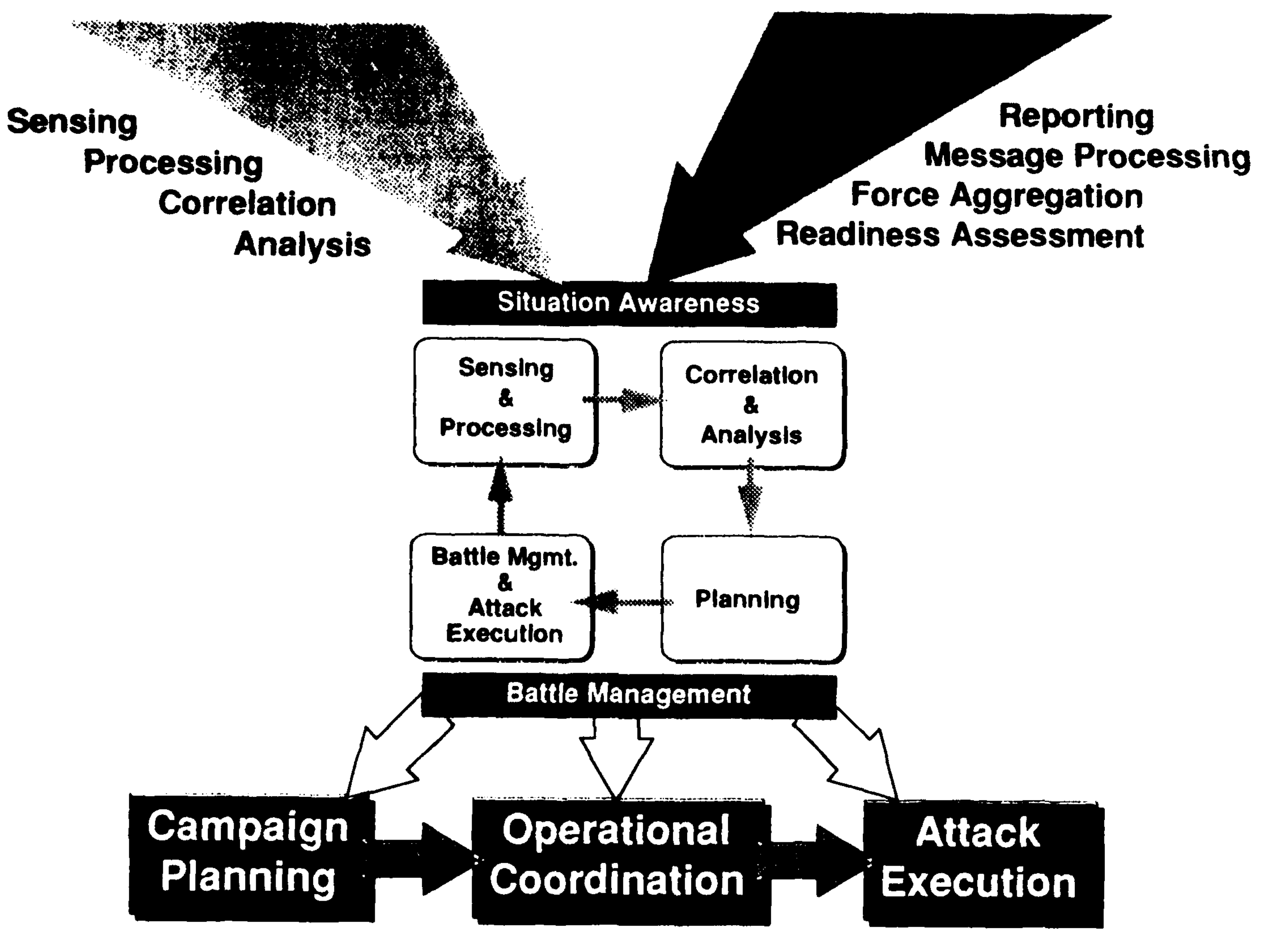

Layered Approach to Sensing and Processing

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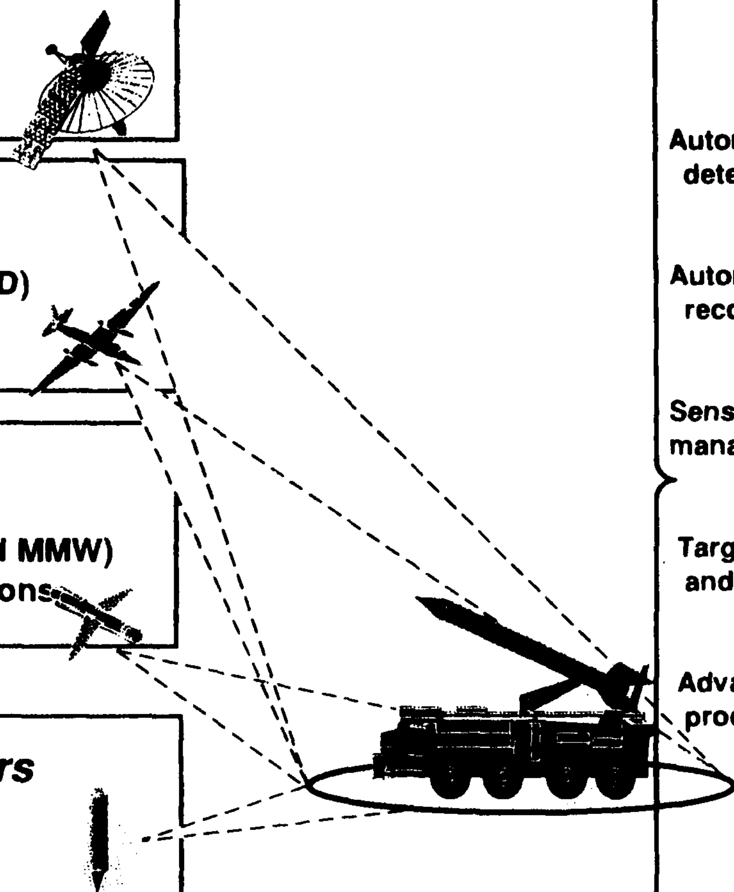
- Advanced sensor suite (FLIR and MMW)
- Manned and unmanned applications

Unattended Ground Sensors
- Extended range sensors
- Auto detect and report



Automatic target detection

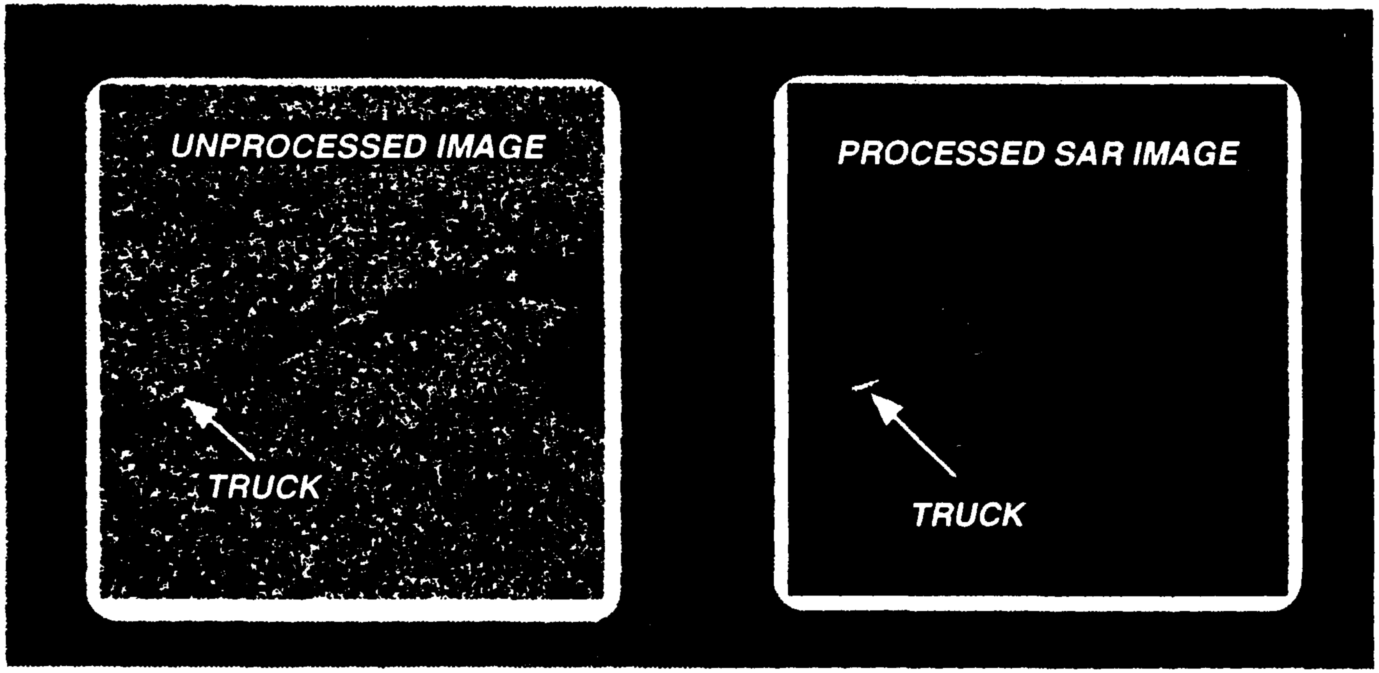
Automatic target recognition

Sensor management

Target signatures and phenomenology

Advanced processors

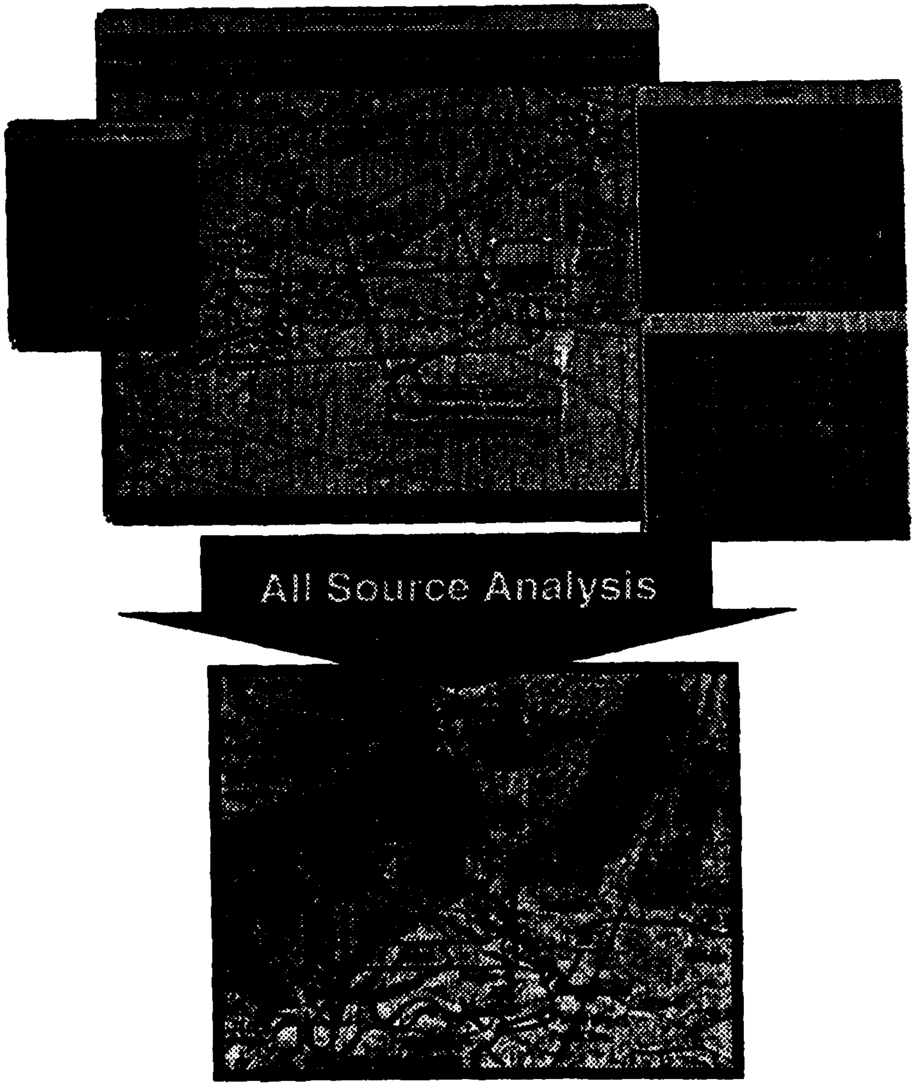
Targets In Clutter



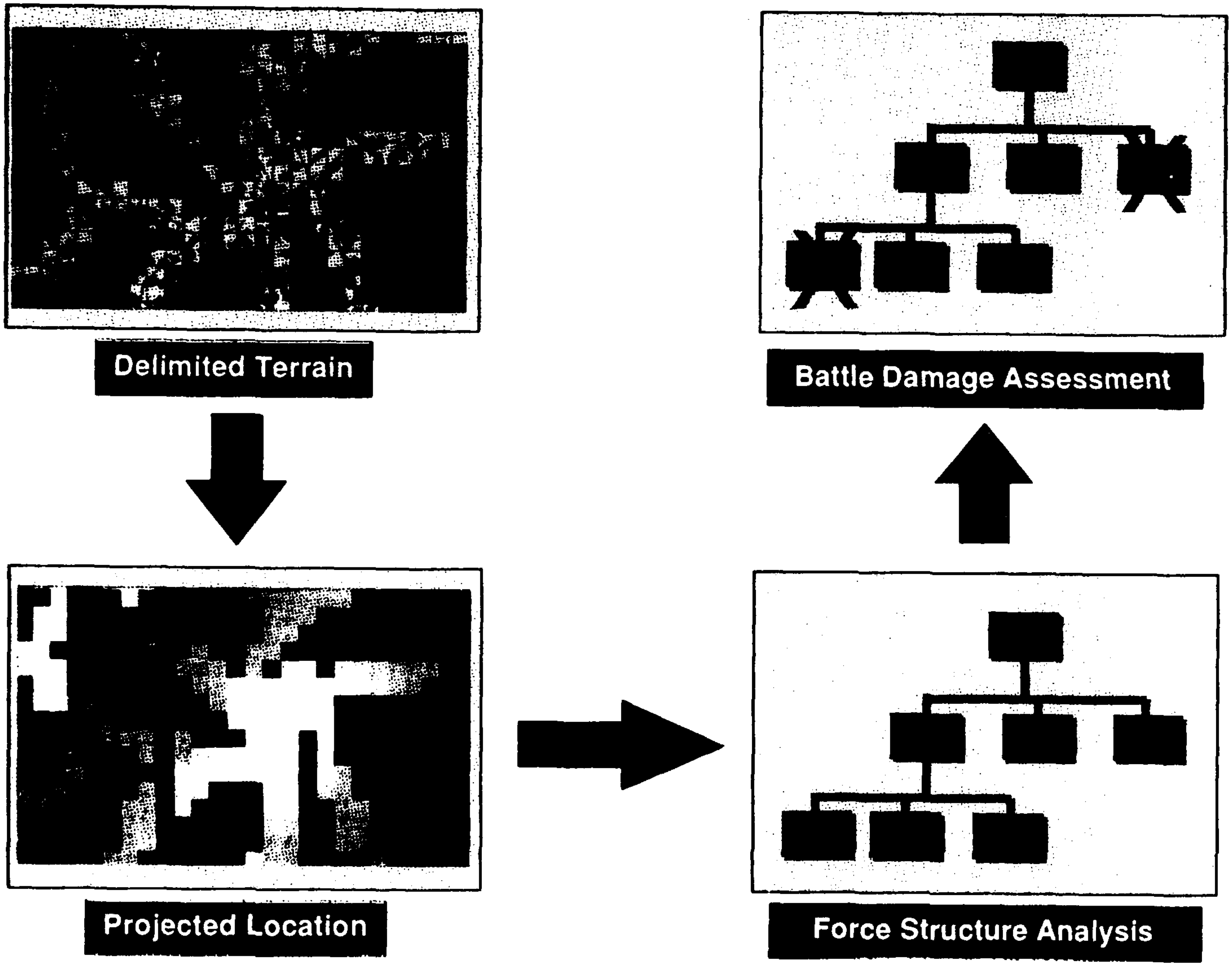
UWB Image

Truck Located

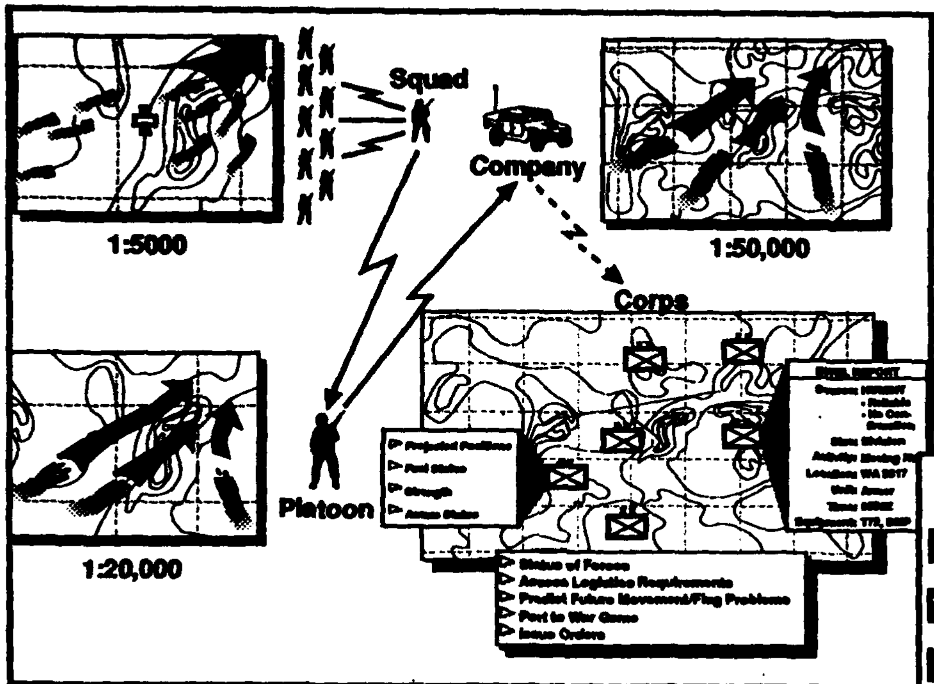
Correlation and Fusion



Automated Analysis

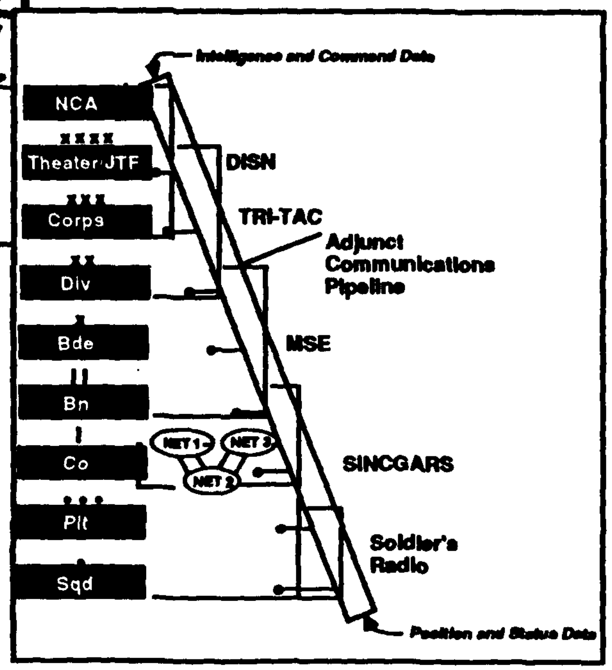


Battle Management Support Technologies



Visualization and Planning

Integrated Communication



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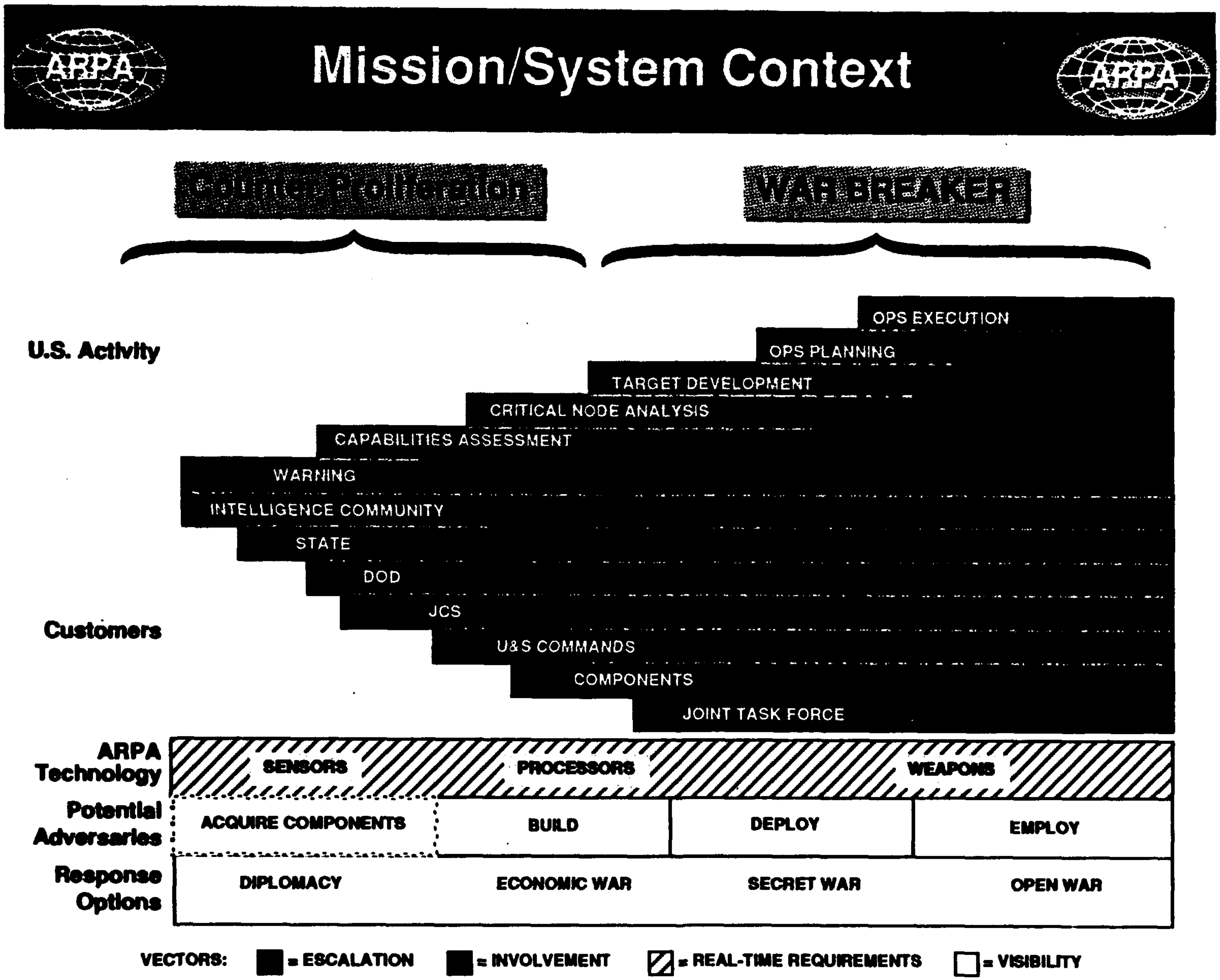
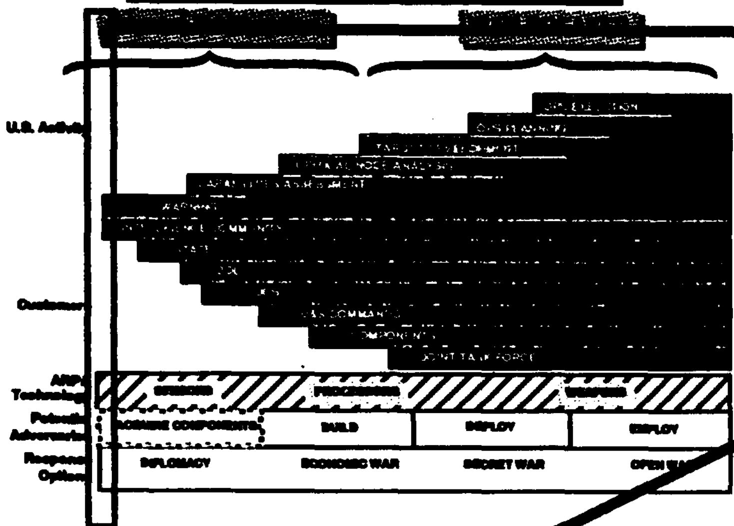
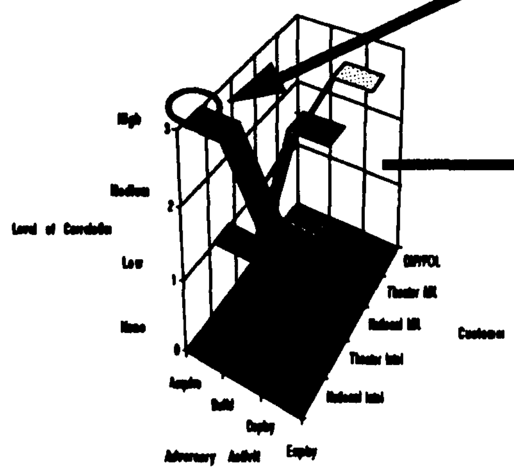


Technology Payoff Identifcation

System Development Context

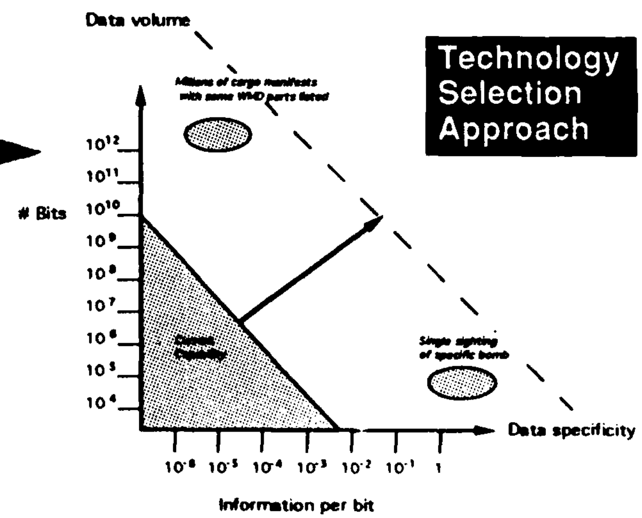


Blue Activity (e.g. Warning)
Blue Entity (e.g. Inter Community)
Enabling Technology (e.g. Sensors)
Red Activity (e.g. Acquire Components)
Blue Responses (e.g. Diplomacy)

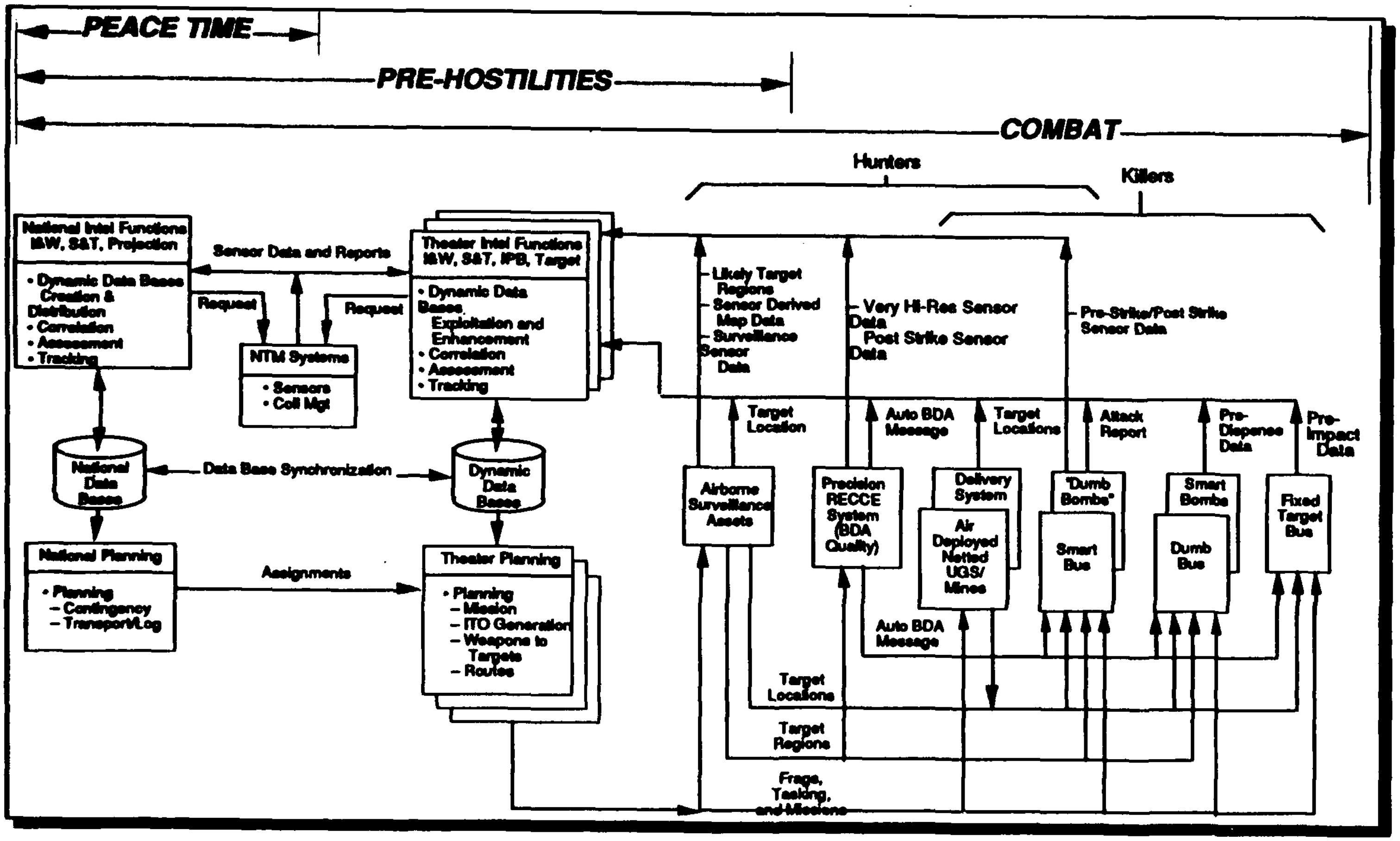


Customer/Activity/Technology/Mapping

Technology Selection Approach



WARBREAKER System Context



Situation Awareness Must Be Tailored to Mission/System

	WARBREAKER	Counter Proliferation
Goal	Get inside enemy cycle times	Support detection, monitoring and interdiction of WMD proliferation
Customers	Services, CINCs,JTF CMDRs	Diplomatic, intelligence, arms control, policy communities
Functions	Support to targeting	I&W, capability assessment, support to critical node analysis and response option generation
Time Frame	Days, hours, minutes	Years, months, weeks
Processing Paradigm	Full automation	Human-computer system
Dominant Target Feature	Mobility	Fixed and mobile mix
Intentions Analysis	Peripheral (Relatively easy)	Central (Difficult)

Situation Awareness and Battle Management Combine Synergisticly